ecosys économie appliquée et environnementale

ASSESSMENT OF THE ECONOMIC, SOCIAL AND ENVIRONMENT BENEFITS OF THE RUBAYA GREEN VILLAGE IN GICUMBI DISTRICT, RWANDA, AND BENEFITS OF PROJECT REPLICATION

On behalf of PEI, UNDP, UNEP and REMA

UNDP Empowered lives. Resilient nations.

REPUBULIKA Y'U RWANDA

UBUMWE - UMURIMO - GUKUNDA IGIHUGU

UNEP

Final report, 23.05.2017

Author :

Dr. D. Maradan, Dir. ecosys SA

Executive summary

I Context

The Rubaya green village demonstration project was initiated and led by Rwanda Environment Management Authority (REMA) and designed and implemented by a range of Government agencies including Ministry of Local Government (MINLOC), Ministry of Agriculture (MINAGRI), Ministry of Natural Resources (MINIRENA), Ministry of Infrastructure (MININFRA) the Rwanda Housing Authority (RHA) and the Gicumbi District with the support of the UNDP-UNEP Poverty-Environment Initiative (phase II), in order to demonstrate or showcase how integrated environmental and natural resource management approaches can address the challenge of poverty reduction and economic development in a sustainable way and in a participatory integrated approach.

The project is of crucial importance to address some of the components when implementing relevant components of the Vision 2020 Umurenge and the rural settlement policy.

A green village includes a number of inter-linked components, emphasizing the efficient, effective, fair and sustainable use of natural resources, using technologies that optimize social, economic and environmental benefits.

In the case of the Rubaya green village demonstration project, the project includes:

- the provision of water reservoirs to control run-off and ensure that water is available to the beneficiaries throughout the year at low opportunity cost. This generates health and economic benefits to the village households.
- The provision of sanitation in order to decrease the prevalence of waterborne disease and related production loss.
- The development of terraces and soil erosion control techniques (including agro-forestry) in order to reduce soil fertility loss and improve agricultural productivity.
- The development of livestock through the implementation of the "One Cow per family program". The distribution of cows generates multiple benefits such as increasing incomes (milk and meat production), dietary composition and manure production for improved soil fertility.
- The provision of digesters in order to provide household with a clean cooking fuel. The use of biogas decreases the use of wood for fuel, avoids deforestation, provides manure for crop cultivation, increases indoor air quality and limits the negative impact of smoke and particle matter on the health of the beneficiaries. Digesters also value human and animal waste preventing water stocks pollution and waterborne diseases.
- The construction of iron-roofed houses each covering a usable space of 100 square meters, which enable rain water harvesting and improve the quality of life as well as the security of the households.
- The construction of a school close to the village in order to increase school attendance among the children.

II Objectives of the assessment

The objective of the present assessment is to determine **to what extent the Rubaya green village demonstration project has been successful in raising the well-being of the beneficiaries while, at the same time, ensuring the sustainable use of natural resources and social cohesion**.

To answer the previous question, a cost-benefit and replication analysis are proposed in order to

1) Determining the net economic, social and environmental benefits of the Rubaya green village demonstration project.

2) Identify the potential net benefits to Rwanda in order to justify the replication of the Rubaya green village demonstration project and to make the case for the Government and development partners to invest in the widespread replication of the project.

3) Identify the potential improvements to the design and implementation of green villages.

III Main costs and benefits of the project

The most relevant benefits and costs of the components of the Rubaya green village demonstration project are described in the tables R1 and R2.

Table R1 : Inventory of project's costs

Type of costs	Costs
Initial investment cost	**Farming** : 8.7 hectares of terraces are available for the beneficiaries. Costs include the cost of land and costs of constructing terraces
	Houses : Construction of 43 houses with hard roof top. The costs include also the land cost.
	Water and sanitation : Reservoirs, filters and water harvesting system (pipes and taps): 7 structures of 100 cubic meter each storing filtered and purified water from roof tops; covered pit latrine with the piping of waste to the bio- digesters
	Livestock : Distribution of 86 cows (breed heifers), 43 have been distributed to habitants of the village while 43 have been distributed to habitants of the surroundings. These latter cows remain however in the village to feed the biogas system. The project also financed cowsheds and feeder for the cows
	Education: Construction a school (3 buildings, 8 classrooms)
	Energy and forest : Digesters and biogas delivery system (7 biogas digesters, 2 of which have capacity of 100m3 each, while 5 others have a capacity of 50 m3 each, totaling to 450 m3). Waste collecting facility (for the storage of manure), biogas stoves (distribution of 43 stoves)
	Project planning : Relocation costs of the beneficiaries, management provided by REMA and PEI
Operating costs	Maintenance of the terraces
	Maintenance of houses
	Maintenance of the water harvesting system and reservoirs
	Maintenance of the cows (medicine, food) and cowsheds
	Maintenance of school and operating of the school (teachers wages and education material)
	Maintenance and operating (in-kind contribution by the beneficiaries) of the digester and biogas delivery system
	Project monitoring and capacity building

Table R2 : Inventory of project's benefits

Categories	Benefits
Farming	Additional value added compared to the situation without the project due to : • Lower loss due to erosion control (terraces) • Higher yield due to the use of manure
Livestock	Additional value added compared to the situation without the project due to • Production of calves • Production of meat • Production of milk • Production of manure
Water & sanitation	The increase the daily availability and quality of water compared to the situation without the project generates : • Additional income from the selling of water • Health and economic benefit (lower health cost, gain of working and education days) due to the lower prevalence of waterborne related diseases for the habitants of the village and the surroundings • Time saving due to the lower distance to fetch for water for the habitants of the village and the surroundings
Energy and forest	The use of biogas for cooking compared to the situation without the project leads to: • Health and economic benefit (lower health cost, gain of working and education days) due to the better indoor air quality (the use of wood or charcoal for cooking generates smoke and particle matter) • Time gain related to the lower necessity to collect wood • Lower pressure on the forest ecosystem. • Reduction of greenhouse gases (GHG) emissions by the use of biogas (without the project, GHG emission resulting from the decomposition of organic waste would have happened anyway. Furthermore, GHG emissions from the burning of wood would have happened)
Education	The availability of education services nearby compared to the situation without the project generates • Higher rate of school attendance by the children living in the region increase the economic rate of return of education (higher productivity of labour) • The proximity of the school generates time saving for the children
Better housing	The availability of more secured, better quality and larger houses compared to the situation without the project generates a gain of welfare (better quality of life) for the beneficiaries.
Exposure to natural disaster	The displacement of the beneficiaries to areas with less steep slopes and that are more secure reduces their exposure to natural disasters, especially due to excessive rainfall. Compared to the situation before the project, this lead to a lower amount of degradation and economic loss (crops production, livestock, houses).
Social cohesion	The people belong to a community that share some risks and opportunities. The community has a great importance to the beneficiaries. They declare they feel more secure, better integrated in society and more confident for the future.

All major costs and benefits have been included in the CBA except the benefits of social cohesion since no methodology is available for estimating the value of such social benefit at the moment.

III Main results

a) Cost-Benefit Analysis

The results of the CBA (table R3) indicate that the project is efficient when 6% and 3% discount rates are considered, over 15, 20 and 30-year periods. The project is also close to efficiency using a 10% discount rate over 30 years.

Considering the highest values for each parameter (i.e. a 6% discount rate and 20 and 30-year periods), the project efficiency is high, leading to benefits surpassing the costs by 15% to 35%. The rate of return also appears to be high (20% and 47%), way higher than any return rate one could obtain through private banking. The internal rate of return over a 30-year period stands at 8.9%, above the 7.7% rate of the 20-year span. Finally, the payback period is of close to 15 years with a 6% discount rate.

All these results prove the project efficiency is high if a sustainable, social and long-term perspective is adopted. However, (private) investors whose emphasis is on short term financial returns only would be unlikely to use their own fund to build projects similar to the Rubaya demonstration project on the basis the lack of financial benefits to them. This gap between national economic benefits and private sector financial benefits is a key rationale for mobilising public sector funds (government and donor) to fund the scaling up of the village.

Table R3 : CBA results (based on central estimates)

	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	145'368	370'879	733'398
	6%	-9'679	125'161	301'311
	10%	-154'671	-85'055	-14'949
	13%	-232'438	-189'297	-153'152
B/C	3%	1.17	1.41	1.76
	6%	0.99	1.15	1.35
	10%	0.80	0.89	0.98
	13%	0.69	0.75	0.80
RoR	3%	23%	58%	115%
	6%	-2%	20%	47%
	10%	-24%	-13%	-2%
	13%	-36%	-30%	-24%
IRR		5.8%	7.7%	8.9%
Payback period	3%	12-13 years		
	6%	15-16 years		
	10%	30-31 years		
	13%	>31 years		

The sensitivity test overall confirms these conclusions. The project has generated more benefits than costs (considering a 6% discount rate over 30 years). Applying 20% margins of error on the costs or benefits does not modify the previous conclusion. Furthermore, no monetary estimate of the benefits of social cohesion, which are described as important by the beneficiary, could be determined. Therefore, the previous results might even underestimate the efficiency of the project. **These results provide thus reliable, decisive and strong arguments in favour of the project's extension and replication.**

b) Replication and scaling up

The extension (to 100 households) of the Rubaya green village demonstration project will generate additional costs for 1.16 million USD over 30 years (using a 6% discount rate) and benefits of around 1.56 million USD over 30 years (using a 6% discount rate), leading to an additional NPV of 0.4 million (table 40). Focusing on the investment cost, 800’000 to 900’000 USD are necessary to support the extension of the Rubaya green village demonstration project to 100 households.

Scaling the project up to 30 additional green villages in Rwanda (3000 beneficiary households) would require an investment of 48.3 millions of USD. This sum represents 1.8% of the budgeted spending of Rwanda for 2016, 4.2% of the development spending or 13.6% of the budget allocated to the rural development objective (according to MINECOFIN, 2016). The estimate take also into account the cost information available for the village of Rweru as well as available information on the IDP Model Villages in Rwanda.

The up-scaling of the project will generate additional benefits leading to a net present value of 21 to 23 millions USD (after 30 years, considering a 6% discount rate). The up-scaling will also generate indirect economic effects, which are estimated at 0.8% of national GDP (63.3 millions of USD).

Scaling-up the project will also have an effect on poverty leading to a decrease of 0.71% of the extreme poverty rate of the country (16.3% in Rwanda in 2015).

IV Success factors and improvement opportunities

The selection of beneficiaries constitutes a key issue. Indeed, the quality of life in Rubaya green village demonstration project is higher than in the surrounding areas. Such differences may lead to jealousy and animosity between beneficiaries and non-beneficiaries. In the case of the Rubaya and Rweru villages, the selection process was successful in avoiding such outcomes. Indeed, beneficiary households were chosen by the local community on the basis of the poverty status and were not imposed from outside. Furthermore, the project benefits have been extended beyond the targeted group (distribution of cows, access to school, water availability). Beneficiaries though faced some constraints during the transition phases (distance to relatives, distance to former farming areas which were still in production during the transition period).

The **creation of a community** was important not only for the people living in Rubaya but also for organizing the village and the related production. The creation of the cooperative strengthened the togetherness of the community and has constituted an essential factor for the caring of the common infrastructure, to manage conflicts and to provide security.

Capacity building efforts constitute a third key factor of the project's success. Those efforts have raised the awareness of the beneficiaries and empowered them with the skills to work together as a community and to manage the project assets responsibly and sustainably. Furthermore, as expressed by Twesigye-Bakwatsa and Bizoza (2014), the training strengthens the collective mobilisation of the beneficiaries and the emphasis on common property and resource sharing arrangements. These have enabled mutual support so that the most vulnerable members are able to manage the facilities (e.g. biogas and water) and economic assets (cows managed in collective sheds) provided by the project.

The **collaboration between key stakeholders and institutions** early in the project design appears also very important. The project design team regularly consulted with the local authorities at the district and sector level during scoping activities, shared preliminary concepts and budget data with them, and held joint planning sessions with local technical and political leadership. By the time it was formally launched at community level in July 2008, the project was already "owned" by local authorities. Initial efforts to integrate in and align the project activities with local authorities' activities secure also early understanding, interest and direct involvement in project activities by local authorities, thereby fostering ownership. The intersectoral coordination was clearly a key success factor since it would have been otherwise very difficult for one single institution to manage the village.

The **improvement opportunities** concern several dimensions the project. First, if replicated at a larger scale, it should be possible to lower some of the costs of the project. In Rubaya, some cost figures appear to be high (compared to regional average such as the price of cows, the investment costs for the waste and sanitation system, the house construction costs). The benefit of the project could be enhanced by facilitating the transport of milk to the market and/or by developing a milk processing installation. The structure of the biogas infrastructure could also be adjusted to minimize the consequence of technical incidents and resulting from the lack of dung. The way the tree nursery was built and used could also to be reshaped.

One important improvement opportunity related to also the transition period (especially for the farming season after the arrival of the household in the new village). Indeed, it has been problematic for some households, since they have still to take care of their former farming land during a few months (if not they will lose one whole harvest), which might be far from the new home. This has been presented by some households as a major problem.

A monitoring tool should be put in place. Such tool would facilitate the collection and selection of key data and the follow-up indicators. Such tools might take the form of a real-time impact evaluation, where costs and benefits would be monitored continuously, with possibilities for fine tuning (of the costs and benefits) throughout the time of project implementation.

Finally, it could be interesting to conduct a cost-benefit analysis for the full-scale nation-wide project, which is based on location-specific information from the identified villages. Such analysis would provide a more representative picture given the socio-economic and bio-physical diversity across the country. Such study would however be costly and requires ample time, even if such cost might be small compared to the total investment.

Syllabus

List of tables

List of figures

Part I : Introduction

1. Introduction

The objective of the report is to determine to what extent the Rubaya green village demonstration project has been successful in raising the well-being of the beneficiaries while, at the same time, ensuring the sustainable use of natural resources and improving social cohesion. In other words, it aims at determining if the Rubaya green village demonstration project was economically, socially and environmentally viable. It therefore fulfils the need to present well substantiated evidences on this issue to key decision and policy makers alike.

This report aims more specifically at:

1) Determining the net economic, social and environmental benefits of the Rubaya green village demonstration project.

2) Identifying the potential net benefits to Rwanda in order to justify the replication of the Rubaya green village demonstration project and to make the case for the Government and development partners to invest in the widespread replication of the project.

3) Identifying the potential improvements to the design and implementation of green villages.

In order to provide relevant answers, a Cost-Benefit Analysis (CBA) was undertaken. The CBA is an analytical tool by which policies or projects are analysed to identify their net economic benefits. Simply stated, the benefits of a given situation or policy-related action are summed, and then the costs associated with taking that action are subtracted. A cost-benefit analysis also takes into consideration intangible items such as the benefits and costs associated with better health or easier access to education. The CBA focuses on the question of efficiency: are the benefits provided by the project larger than its cost ? Therefore, it does not consider other criteria such as distributives consequences (among income categories, gender, generation), its relevance or its legal compliance.

The report is organized as follows. Part I presents the context and describes briefly the Rubaya green village demonstration project experience. The second part is devoted to the presentation of the CBA. The scaling-up analysis and related business plan is the focus of Part III.

2. The context and project description

The Rubaya demonstration project was initiated and led by REMA and designed and implemented by a range of Government agencies including Ministry of Local Government (MINALOC), Ministry of Agriculture (MINAGRI), Ministry of Natural Resources (MINIRENA), Ministry of Infrastructure (MININFRA), Rwanda Housing Authority (RHA) and the Gicumbi District with the support of the UNDP-UNEP Poverty-Environment Initiative (phase II) in order to demonstrate or showcase how integrated environmental and natural resource management approaches can address the challenge of poverty reduction and economic development in a sustainable way and in a participatory integrated approach. The project is of crucial importance in addressing some of the components of modern green villages when implementing relevant components of the Vision 2020 Umurenge and the rural settlement policy.

The green village project is part of the itinerary towards realizing the Vision 2020, the country's overarching national planning and policy framework. It also supports key policies objectives of the Economic Development and Poverty Reduction Strategy (EDPRS I&II). More specifically, the green villages aim at fostering the achievement of the following key national priorities:

- Ensuring access to adequate, nutritious food for all households, especially the poorest.
- Ensuring access to adequate clean water for all households through integrated water management approach
- Increasing the production of marketable products and enhancing the development of cooperatives
- Ensuring the use of adequate clean, affordable and environmentally friendly energy for cooking, heating and lighting.

- Strengthening the protection of households in scattered settlements, e.g. in areas with steep slopes, from climate-related disasters.
- Fast-tracking reduction of absolute poverty through direct asset transfers; fostering community support and capacity building of social institutions.
- Reducing poverty levels and more generally improving livelihoods in a sustained manner
- Fostering unity, reconciliation and cohesion among resource-poor people, living in sub-standard scattered settlements.

Green villages have been designed as a tool for translating the previous policy objectives into practical tangible actions. The Rwandan Government had decided to support the development of additional “model green villages” in the country under the National Human Settlement Policy and Strategy. The objective state that all district development plans have to include at least one green village. New green villages have already been realized (e.g. Rweru, Gashaki, Kibangira). These villages share the characteristics of Rubaya, but might include additional components (such as irrigation or electricity).

A green village includes a number of inter-linked components, emphasizing the efficient, effective, fair and sustainable use of natural resources, and using technologies that optimize social, economic and environmental benefits. A green village rests on the implementation of different components, which are described in the toolkit of the development of smart green villages in Rwanda (UNPE-UNDP, 2015). In the case of the Rubaya green village demonstration project, the project includes:

- the provision of water reservoirs to control run-off and ensure that water is available to the beneficiaries throughout the year at low opportunity cost. This generates health and economic benefits to the village households.
- The provision of sanitation in order to decrease the prevalence of waterborne disease and related production loss.
- The development of terraces and soil erosion control techniques (including agro-forestry) in order to reduce soil fertility loss and improve agricultural productivity.
- The development of livestock through the implementation of the "One Cow per family program". The distribution of cows generates multiple benefits such as increasing incomes (milk and meat production), dietary composition and manure production for improved soil fertility.
- The provision of digesters in order to provide household with a clean cooking fuel. The use of biogas decreases the use of wood for fuel, avoids deforestation, provides manure for crop cultivation, increases indoor air quality and limits the negative impact of smoke and particle matter on the health of the beneficiaries. Digesters also value human and animal waste preventing water stocks pollution and waterborne diseases.
- The construction of iron-roofed houses each covering a usable space of 100 square meters, which enable rain water harvesting and improve the quality of life as well as the security of the households.
- The construction of a school close to the village in order to increase school attendance among the children.

The previous elements compose a sustainable system whose logic of action is presented in the figure 1 below. The welfare and income benefits are generated by the interactions of better producing assets and conditions (lower soil erosion, higher soil fertility, cows and milk production), better life conditions (water quality and availability, biogas, houses), lower burden of disease (indoor air quality, better nutrition, improved water quality), time saving (water and wood collection, distance to go to school) and better access to education.

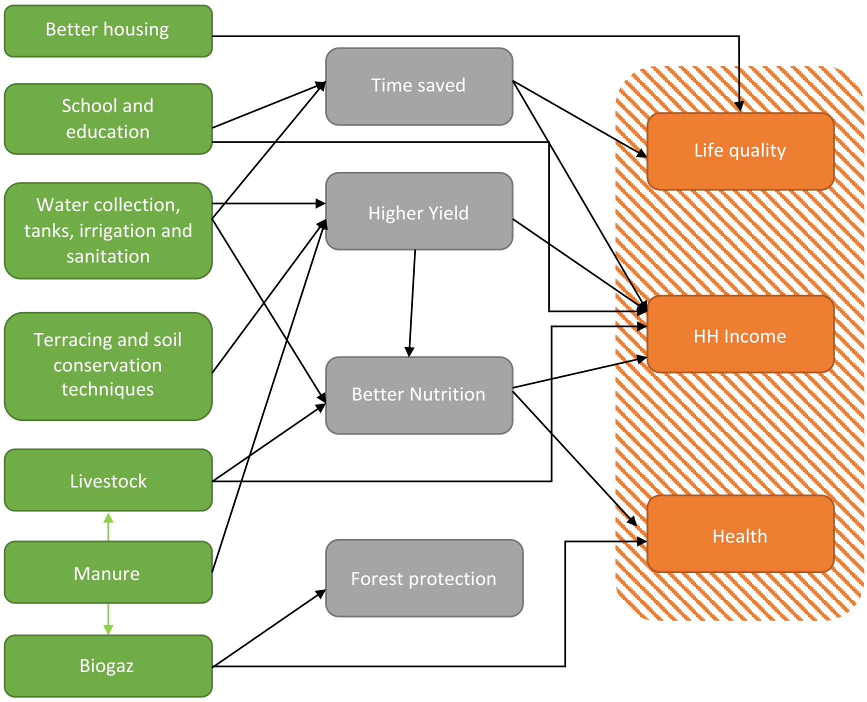

Figure 1 : Logic of actions of the green village model

The local community participates actively in the selection of the beneficiaries among the poorest households and individuals, poverty status being based on the Ubudehe[1] ranking. The project's participatory assessment and planning activities pay particular attention to ensuring the active participation of women and other marginalized groups, as a failure to take their specific concerns into consideration could negatively affect some of the project outcomes.

Knowing that the Rubaya sector was identified as one of the 30 poorest sectors of the country, the demonstration project clearly puts a strong emphasis on the conditions that should allow the beneficiaries to overcome the poverty trap.

It should also be noted that a critical attribute for the demonstration project planning was the involvement of the beneficiaries in the construction of houses and infrastructures as well as in the operation of the water and biogas systems. In order to facilitated the management of the infrastructure, a cooperative was created. This clearly strengthen the social dimension of the village. Note also that the realization of the village requires an effective intersectoral coordination between all major contributors (Local government, Ministries and International Organizations).

The Rubaya green village demonstration project covers around 15 hectares on a gentle sloping area. Initially, the project targeted 100 households but has been limited to 43 households because of budgetary constraints. In 2016 (around 5 years after its start), at the time of visit of the consultant, the Rubaya green village demonstration project counts indeed 43 households and 207 habitants. It is still planned by the Ministry of Local Government (MINALOC) to add 57 households in the village, supported financially by an investment under a planned project supported by the Green Climate Fund.

The Rubaya green village demonstration project was based on :

- The construction of 43 iron-roofed houses each covering a usable space of 100 m^2, with 3 bedrooms, a kitchen and a bathroom, and water collection gutters;
- The construction of roof-top water harvesting, treatment and supply facilities for domestic water use;

1 Household vulnerability in Rwanda is often defined not only by pure consumption poverty but also by households' ranking under the system known as Ubudehe. Ubudehe refers to the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community.

- The construction of water-borne, ventilation-improved pit (VIP) latrines for 43 households;
- The construction of 7 biogas digesters, 2 of which have capacity of 100m3 each, while 5 others have a capacity of 50 m3 each, totaling to 450 m3; and a waste collecting facility (collection and storage of manure);
- The provision of 86 improved breed heifers to each of the 43 beneficiary households and 43 neighboring households;
- The construction of communal cowsheds;
- The construction of a school located in the village.

3. Working phases

The study "Assessment of the economic, social and environment benefits of the Rubaya green village demonstration project in Gicumbi district, Rwanda, and benefits of project replication" was carried out between December 2016 and March 2017. Its preparation has included three distinct phases. **During the first inception phase**, we collected information and data on the Rubaya green village as well as similar projects held in Rwanda. Two previous incomplete economic analyses (Twesigye-Bakwatsa C. and Bizoza A.R., 2014; Borde A. and Rangira L., 2016) on the Rubaya green village demonstration project provide some valuable information on the village. The inception phase has ended with the approval of the inception report in January 2016. The inception report presents the analytical principle (time span, discount rate, reference case) and the expected results, lists all the cost and benefits of the village and proposes valuation methodologies for estimating the monetary values of the intangible benefits.

The second phase of the study consisted of analyzing the data and building up the CBA and the replication analysis. A mission in Rwanda (30.01.17 - 08.02.17) was organized in order to interview the project's stakeholders (PEI in Rwanda, REMA, MINAGRI, MINALOC, NISR, Gicumbi District Authorities) and the beneficiaries. A one day field visit in Rubaya has allowed to check the information and to complete some of the data. We also interviewed beneficiary households in order to verify if the observations they made earlier on the project remains valid. We also visited the model green village in Rweru (Bugesera District) in order to comprehend the degree of similarity between the pilot and upscaling projects. This was important in order to propose a relevant replication and scaling-up model. In Rweru, we had also the chance to discuss with village beneficiaries. We ended up the second phase by finalizing and sharing with REMA and PEI the results of the CBA.

The third phase consisted of revising the CBA and scaling up analysis according to stakeholders' remarks. The third phase ended up writing the final report, and this was presented in a Validation Workshop on 4th May 2017 with some 30 stakeholders participating. Comments emanating from this validation workshop have been integrated in this document.

Part II : Cost-Benefit analysis

1. The CBA process and methodology

1.1 CBA analytical steps

As recommended by Organization of Economic Cooperation and Development (OECD, 2006), the cost benefit analysis of the Rubaya demonstration project will follow a 6 steps process.

The first step determines the objectives of the CBA. As mentioned in the introduction, it aims at determining if the Net Present Value (NPV) of the Rubaya demonstration is larger than zero when its economic, environmental and social benefits are taken into consideration.

Step 2 consists in identifying the costs and benefits of the project. This is not a straightforward issue since the analyst has to identify only the benefits and costs that result from the project and not those that would have taken place even without the project. In order to do so, the reference or business as usual scenario (the situation without the project) has to be described and estimated so that only the incremental (or additional) costs and benefits rising from the project are taken into consideration. In the case of the Rubaya demonstration project, determining the situation of the beneficiaries without the project can be achieved by comparing their situation to the one of non-beneficiaries. The monitoring of such control group is of course difficult in social sciences where laboratory conditions do not exist. In the case of the Rubaya demonstration project, the initial analysis undertaken by Twesigye-Bakwatsa and Bizoza (2014) gives valuable information on the situation of non-beneficiaries (control group). However, in some cases, identifying the "without the project situation" has to be extrapolated from data on the situation of the beneficiaries before the project.

Step 3 determines the monetary value of the costs and benefits. The valuation of market values is straightforward. It mainly rests on the collection of data on the physical quantity and market prices (before tax), wages and rate of return. The valuation of intangible costs and benefits rests on the use of monetary valuation methodologies. In the Rubaya CBA, the valuation of non-market benefits has been mainly achieved by valuing the market consequences of such benefits (for example, a better access to sanitation has market consequences since it reduces health costs and increases the productivity of labour). When available, values specific to Rwanda were used in the valuation process. Otherwise, benefit transfers (values issued from similar situations but in other countries) were applied.

Step 4 consists in discounting the costs and benefits and aggregating them. Indicators of the efficiency of the project are computed as the NPV, the B/C ratios, the rate of return, the payback period and the internal rate of return.

Step 5 performs a sensitivity analysis by considering margins of error on the costs and benefits estimates as well as on discount rates. The sensitivity analysis grasps the principal uncertainties of the analysis by determining how resilient the results of the analysis are to alternative hypothesis or data.

Step 6 aims to give recommendations. These recommendations indicate on the one hand how the efficiency of the project could be increased. On the other, they address the CBA itself, indicating how the limits or drawbacks of the analysis could be overcome.

1.2 The CBA results

Simply stated, the CBA allows to identify the net present value (NPV) of a project or policy. "Net" means that the costs of a project are subtracted from its benefits, indicating if a project is beneficial or not. "Present" means that the analysis weighs (i.e. discounts) the costs and the benefits of the project according to their timing. Discounting makes current costs and benefits worth more than those occurring in the future because there is an opportunity cost to spending money now and there is a preference for enjoying benefits now rather than in the future. Accordingly, the following CBA aims at measuring the net present value of the Rubaya green village demonstration project. If the net present value is positive (or large in comparison to other projects pursuing similar objectives), it constitutes an argument for scale-up (through replication, expansion or other modalities) of the best practices and lessons learnt, to other districts and provinces of the country. On the other hand, if the NPV value is negative (or low in comparison to other projects pursuing similar objectives), it constitutes an argument for not replicating the project. The CBA analysis allows the computing of several complementary indicators of the project efficiency. They are briefly presented in table 1.

Table 1 : Indicators of project efficiency

Indicators	Definition
Net present value (NPV)	Total present benefit – Total present cost
Benefit to cost ratio (B/C)	Total present benefit / Total present cost
Rate of return (RoR)	Total present benefit / initial investment cost
Payback period	The length of time required to get the necessary benefit to cover the cost of the initial investment.
Internal rate of return (IRR)	The discount rate that makes the net present value (NPV) equal to zero

The CBA is also a process of analysis, which includes the collection of evidence, consultations and interviews with major stakeholders and project beneficiaries and comparisons across projects. It therefore allows us to identify how the project could be improved if replicated at a similar or larger scale.

1.3 Time span and discount rate

The project started in 2008/09 with the construction phase. Accordingly, most of the benefits of the project were available during 2011 (cows have been distributed in 2011). In the CBA, the costs and benefits will be estimated over 20 years. The sensitivity analysis adjusts this time span to 30 and 15 years. All investment costs are attributed to year 0 while operating costs and benefits are being recorded from year 1 to 20 (respectively 30). Annual benefits and operating costs are usually held constant over the life span of the project, except for the benefits of livestock and terracing, which appear gradually over time.

The choice of a discount rate is necessary to weight future costs and benefits. As stated by Independent Economic Advisers (2009), even if there is no agreement on the value of the social discount rate, there is agreement on what analysts and policymakers should do in the face of the uncertainty about the appropriate discount rate: the importance of the sensitivity analysis. That is, they need to make sure that their analysis considers several discount rate scenarios, not just a very low or high one. Independent Economic Advisers (2009) recommends that the range of discount rates to consider should include a rate close to the market discount rate. A sensitivity analysis is thus proposed with the following discount rates: 3%, 6%, 10% and 13%.

Our preferred social discount rate is 6%. This value is justified since the social discount rate has to be lower than the private discount rate, as it reflects the social time preference rate (STPR). As the minimal rate for the private discount rate is the private interest rate, around 6.5% in Rwanda in 2014-15, 6% appears to be appropriate. The discount rate has to be lower than private interest : market rates overestimate the rate of time preferences since they do not consider all costs (taxation, transaction) nor externalities. 6% also reflects the value that is used in OECD countries and in other CBA analyses in Africa. For example, when estimating the cost of environmental degradation in Morocco, the World Bank (2017) uses a 6% discount rate. The 3% discount rate is a lower benchmark and clearly puts a stronger emphasis on the sustainability of the Rubaya project since it gives the future social and environmental benefits larger weight in the final equation. On the other hand, 13% constitutes an upper benchmark since it is close to the discount rate of the central bank of Rwanda, which is equal to the interest rate at which the central bank lends its money to commercial banks facing short term needs of cash. Such a rate would clearly drastically reduce the profitability of the Rubaya project. 10% is also very high for socially and environmentally oriented project. Indeed, if the NPV value of a project is larger than zero using 10% or 13% discount rate, it should be attractive to private investors.

The discounting formula is:

$$NPV = \sum_{t=1}^{n} \frac{B_n}{(1+r)^n} - \sum_{t=1}^{n} \frac{C_n}{(1+r)^n}$$

With B_t and C_t the benefits and the costs respectively at period t and *r* the discount rate.

2. Identification of the cost and benefits

The identification of the costs and benefits of the project sets the boundaries of the analysis. Costs and benefits have been classified according to 7 categories:

- Farming
- Livestock
- Water and sanitation
- Energy and forest preservation
- Better housing
- Education
- Exposure to natural disasters

On the cost side, two types of costs have been identified: The initial investment costs related to the construction of the village's houses and infrastructures, as well as the operating costs resulting from the running, maintenance and management of the installations. The costs considered in the analysis are listed in table 2.

Table 2 : Inventory of project's costs

Type of costs	Costs
Initial investment cost	**Farming** : 8.7 hectares of terraces are available for the beneficiaries. Costs include the cost of land and costs of constructing terraces **Houses** : Construction of 43 houses with hard roof top. The costs include also the land cost. **Water and sanitation** : Reservoirs, filters and water harvesting system (pipes and taps): 7 structures of 100 cubic meter each storing filtered and purified water from roof tops; covered pit latrine with the piping of waste to the bio- digesters **Livestock** : Distribution of 86 cows (breed heifers), 43 have been distributed to habitant of the village while 43 have been distributed to habitant of the surroundings. These latter cows remain however in the village to feed the biogas system. The project also financed cowsheds and feeder for the cows **Education**: Construction a school (3 buildings, 8 classrooms) **Energy and forest** : Digesters and biogas delivery system (7 biogas digesters, 2 of which have capacity of 100m3 each, while 5 others have a capacity of 50 m3 each, totalling to 450 m3). Waste collecting facility (for the storage of manure), biogas stoves (distribution of 43 stoves) **Project planning** : Relocation costs of the beneficiaries, management provided by REMA and PEI
Operating costs	Maintenance of the terraces Maintenance of houses Maintenance of the water harvesting system and reservoirs Maintenance of the cows (medicine, food) and cowsheds Maintenance of school and operating of the school (teachers wages and education material) Maintenance and operating (in-kind contribution by the beneficiaries) of the digester and biogas delivery system Project monitoring and capacity building

The inventory of the costs has been discussed in detail with the stakeholders as it has consequences on the inventory of the benefits.

Indeed, in order to identify the benefits, the expected consequences of the investment and operating costs are first inventoried. These potential benefits are to be confirmed or not through stakeholder interviews and field visits. At the same time, unfavourable outcomes of the project are also identified. In the case of Rubaya, no significant negative consequence (for the beneficiaries and non-beneficiaries) of the project has been identified. Indeed, the village did not generate additional waste and pollution flows. It also did not reduce drastically the access to some natural or economic resources. This is not to say that there are no improvement possibilities. However, no unexpected and significant negative outcomes (either internal or external) generated by the investment and operating costs have been identified.

A few issues deserve attention:

- The local road was renovated. However, this cost (and the related benefits) has not been considered. We postulated that the road has been upgraded since more people live in the village but this is not linked to the specific attributes of the Rubaya green village demonstration project. In other terms, if any village would have been constructed, the road would also have been renovated.
- MININFRA invested also in charcoal saving stoves for the households (they use principally biogas but need also to use wood and charcoal in some cases). Due to lack of data on the related investment cost, it has not been included. However, the benefits (and costs) of better indoor air quality are accounted for when considering the use of biogas stove.

Table 3 : Inventory of project's benefits

Categories	Benefits
Farming	Additional value added compared to the situation without the project due to : • Lower loss due to erosion control (terraces) • Higher yield due to the use of manure
Livestock	Additional value added compared to the situation without the project due to • Production of calves • Production of meat • Production of milk • Production of manure
Water& sanitation	The increase the daily availability and quality of water compared to the situation without the project generates : • Additional income from the sale of water • Health and economic benefits (lower health cost, gain of working and education days) due to the lower prevalence of waterborne related diseases for the habitants of the village and the surroundings • Time saving due to the lower distance to fetch for water for the habitants of the village and the surroundings
Energy and forest	The use of biogas for cooking compared to the situation without the project leads to: • Health and economic benefit (lower health cost, gain of working and education days) due to the better indoor air quality (the use of wood or charcoal for cooking generates smoke and particle matter) • Time gain related to the lower necessity to collect wood • Lower pressure on the forest ecosystem. • Reduction of greenhouse gases (GHG) emissions by the use of biogas (without the project, GHG emission resulting from the decomposition of organic waste would have happened anyway. Furthermore, GHG emissions from the burning of wood would have happened)
Education	The availability of education services nearby compared to the situation without the project generates • The higher rate of school attendance by the children living in the region increase the economic rate of return of education (higher productivity of labour) • The proximity of the school generates time saving for the children

Categories	Benefits
Better housing	The availability of more secured, better quality and larger houses compared to the situation without the project generates a gain of welfare (better quality of life) for the beneficiaries.
Exposure to natural disaster	The displacement of the beneficiaries to lower slope and more secured areas reduces their exposure to natural disaster. Compared to the situation before the project, this lead to a lower amount of degradation and economic loss (crops production, livestock, houses).
Social cohesion	The people belong to a community sharing some risks and opportunities. The community has a great importance to the beneficiaries. They declare they feel more secure, better integrated in society and more confident for the future.

- The project invested in an irrigation system and solar lamps, but the investment has been abandoned (and not fully realized) since the initial tests were not conclusive. We did not account for the cost nor the benefit of these components since we have not seen any irrigation reservoirs when we visit the Rubaya green village demonstration project in February 2017. A few solar lamps were indeed working but the households have installed them on their own. The inventory of the benefits is presented in table 3. It has also been discussed with the stakeholders. Note that for each benefit, the incremental contribution of the project will be estimated in coherence to the with or without project principle.

3. Monetary evaluation of the project's costs

The initial investment costs of the project have been identified by examining the billing documents (mainly quotations) related to the project. Estimating operating costs also required interviewing of project managers and beneficiaries. In each case, available evidence has in addition been examined in the light of official reports or similar case studies. The field visit has enabled to ensure the investment corresponded to the initial planning and the installations were in operation.

The estimates of the investments and operating costs are presented in table 4 and 5. We built confidence intervals (low – L, central – C and high – H estimates) by considering +/- 10% margin for evidence coming from billing documents or reported by the project managers or beneficiaries. A +/-20% interval is considered if the value has been transferred from existing documents or academic papers. One exception concerns the initial investment as well as yearly maintenance of the terraces, for which three independent unit cost values (low, central and high) had to be used since no billing information was available. Due to the previous hypothesis, the total investment costs range between 570'000 and 710'000 USD (11% interval around the central value). Most of investment costs are due to the infrastructures related to water and sanitation (30%) as well as to the biogas production and delivery system (26%).

Table 4 : Investment costs (USD)

Domains	Description	Low	Central	High	% of total (M)
Farming	Construction of terraces	19'273	23'045	28'402	4%
Livestock	Cows and cowsheds	59'539	68'308	72'769	11%
Water and sanitation	Reservoirs, pumps, filters, toilets	171'854	190'949	210'044	30%
Energy and forest	Biogas system (digester and stoves)	148'947	165'496	182'046	26%
Housing	Houses	93'048	103'387	113'725	16%
Education	School	41'538	46'154	50'769	7%
Project planning	Community work and planning	32'890	41'113	49'336	6%
	TOTAL	**567'089**	**638'452**	**707'091**	**100%**

Table 5 : Operating costs (USD/year)

Domains	Description	Low	Central	High	% of total (M)
Farming	Maintenance of terraces and agro-forestry	240	265	291	1%
Livestock	Maintenance of cowsheds	48	54	59	0%
Water and sanitation	Maintenance of water delivery system and toilets	852	947	1'041	5%
Energy and forest	Maintenance of biogas system	5'055	5'617	6'178	29%
Housing	Maintenance of houses	2'305	2'561	2'817	13%
Education	Teachers wage and education material	5'998	6'665	7'998	34%
Project operation	Monitoring and capacity building	2'816	3'520	4'224	18%
	TOTAL	**17'314**	**19'628**	**22'608**	**100%**

The operating costs range between 17'000 to 22'000 USD per year. At the initial phase of the project, the largest share results from the operating of the school (teacher wages) as well as the maintenance of the biogas system and houses.

It is to be noted however that the distribution of the cost among the domains is not full. For example, the community work ("Umuganda") remains in the domain "project planning" since it contributed potentially to all domains (and no information on its distribution is available). Similarly, the distinction between costs related to the biogas system and sanitation is not clear-cut.

The estimates of the costs are presented in details for each domain in table 6 to 12. Table 6 presents the costs related to the farming activity, mainly terracing the fields and the opportunity of the farming land devoted to the project. As already mentioned, an important issue concerns the unit cost of terracing as no evidence was available in the billing documents (terracing has been financed by the EU, see European Development Fund, 2014). Examining the relevant literature on terracing in Rwanda, three estimates of the unit cost of building and maintaining terraces have thus been identified (low, central and high estimates). For other farming costs, +/-10% intervals have been considered. The costs also include the nursery bed and agro-forestry in order to limit soil erosion.

Table 7 presents the estimates for the costs related to livestock. Note that the feeding cost of the animals is in parenthesis and is not included in the total. The feeding costs have been subtracted from turnover when determining the value added from livestock production. Considering the feeding cost also in the cost side would lead to double counting.

Table 8 shows the costs of water and sanitation infrastructures and related operation costs. Note that the maintenance cost of the sanitation constitutes an in-kind contribution of the beneficiaries (20 minutes per day per household) considering an opportunity cost of time equal to 50% of the rural wage (estimated at 1200 RWF/day and a working time of 8 hours per day).

Table 9 presents the cost of digester and biogas production and distribution (energy and forest domain). As no data have been recorded on the operation costs (but some maintenance has been made), this latter has been transferred (+/-10% confidence interval is thus considered) from Renwick et al. (2007).

Table 10 presents the construction and maintenance cost of the houses (as well as the opportunity cost of the land used for building the houses). As no evidence is available on the maintenance costs, an annual amount representing 2.5% of investment costs has been considered. A similar hypothesis has been made for the maintenance cost of the cowsheds, the nursery beds and the school.

Table 11 shows the estimated costs of the school. The school was built by the project. The total investment costs are thus accounted for. The operation costs (the teachers' wages and education material) are estimated on the basis of unit costs available in the Rwanda Education NGO Coordination Platform (2013). For the operational cost, we consider that the project accelerated the growth of the number of available teachers per children. However, the number of teachers would have been raised later on without the project. We have thus attributed to the project the operational cost of the school would during the first 10 years after the implementation of the school.

Table 12 estimates the project implementation and management costs. The implementation costs include the labour devoted to plan out the project, to hire and organize the construction as well as to select and relocate the beneficiaries. The costs for managing the investment has been estimated at 440 man-days, which are equal to 7040 USD (2 full-time, at 10'400 RWF per day, which corresponds to the average higher education wage level in Rwanda, see wage indicator survey 2012). The community work for realizing the project is estimated at around 32'000 USD. We also consider relocation costs of 860 USD (20 USD per household). The operation costs concern the monitoring and capacity building of the project. Monitoring and capacity building costs are estimated at 3'520 USD/y, which are equal to 220 man-days per year (also considering 10'400 RWF per day).

Table 6 : Costs related to the farming activity

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Terrace construction cost	8.7	ha	L - 1112	USD/ha	9'720	USD	Unit cost : Bizima (2011)
		8.7	ha	C - 1423	USD/ha	12'430	USD	Unit cost : Bizoza et al. (2010)
		8.7	ha	H - 1914	USD/ha	16'725	USD	Unit cost : FAO (2011)
	Nursery beds and agro-forestry					7692	USD	
	Opportunity cost of land	15.2	ha	124'800	RWF/ha	2'923	USD	Unit cost : FAO (2011)
					L - Total	**19'273**	**USD**	-10% if not otherwise mentioned (L, C or H)
					C - Total	**23'045**	**USD**	
					H - Total	**28'402**	**USD**	+10% if not otherwise mentioned (L, C or H)
Operation cost	Maintenance of the terraces, include manure application	8.7	ha	L - 7.6	USD/ha/y	67	USD/y	Unit cost : Bizima (2011)
		8.7	ha	C - 8.4	USD/ha/y	73	USD/y	Average between L and H
		8.7	ha	H - 9.1	USD/ha/y	79	USD/y	Unit cost : FAO (2011)
	Nursery beds					192	USD/y	2.5% of investment
					L - Total	**240**	**USD/y**	-10% if not otherwise mentioned (L, C or H)
					C - Total	**265**	**USD/y**	
					H - Total	**291**	**USD/y**	+10% if not otherwise mentioned (L, C or H)

Table 7 : Costs related to the livestock production

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Animal	86	cows	769	USD/unit	66'154	USD	
	Cowshed	7	cowshed	200'000	RWF/unit	2'154	USD	
					L - Total	**59'539**	**USD**	-10%
					C - Total	**68'308**	**USD**	
					H - Total	**72'769**	**USD**	+10%
Operation cost	Feeding cows	86	cows	55	USD/y	(4730)	USD/y	
	Cowshed					54	USD/y	2.5% of Investment
					L - Total	**48**	**USD/y**	-10%
					C - Total	**54**	**USD/y**	
					H - Total	**59**	**USD/y**	+10%

Table 8 : Costs related to the water and sanitation

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Water reservoirs					14'500	USD	
	Pumps					1'958	USD	
	Filters					7'150	USD	
	Water harvesting system (drainage, pipes, etc.)					160'072	USD	
	Sanitation (eco-toilets)					7'269	USD	
					L - Total	**171'854**	**USD**	-10%
					C - Total	**190'949**	**USD**	
					H - Total	**210'044**	**USD**	+10%
Operation cost	Eco-toilet (time devoted by households)	5232	hours/y	75.0	RWF/h	604	USD/y	
	Water system					343	USD/y	
					L - Total	**852**	**USD/y**	-10%
					C - Total	**947**	**USD/y**	
					H - Total	**1'041**	**USD/y**	+10%

Table 9 : Costs related to the energy and forest

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Digester and distribution system					165'060	USD	
	Stoves	43.0	units	10.2	USD/units	436	USD	
					L - Total	**148'947**	**USD**	-10%
					C - Total	**165'496**	**USD**	
					H - Total	**182'046**	**USD**	+10%
Operation cost	Maintenance costs of digester					733	USD/y	Renwick et al., (2007)
	Labor and water inputs, by households					4'884	USD/y	Renwick et al., (2007)
					L - Total	**5'055**	**USD/y**	-10%
					C - Total	**5'617**	**USD/y**	
					H - Total	**6'178**	**USD/y**	+10%

Table 10 : Costs related to the housing

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Houses construction	43	houses	2'382	USD/unit	102'427	USD	
	Opportunity cost of land	5	ha	124'800	USD/ha	960	USD	
					L - Total	**93'048**	**USD**	-10%
					C - Total	**103'387**	**USD**	
					H - Total	**113'725**	**USD**	+10%
Operation cost	House maintenance cost					2561	USD/y	2.5% of Investment
					L - Total	**2'305**	**USD/y**	-10%
					C - Total	**2'561**	**USD/y**	
					H - Total	**2'817**	**USD/y**	+10%

Table 11 : Costs related to Education

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	School construction (including land)					46'154	USD	
					L - Total	**41'538**	**USD**	-10%
					C - Total	**46'154**	**USD**	
					H - Total	**50'769**	**USD**	+10%
Operation cost	Education material	252	schoolchild	3'500	RWF/y	1'357	USD/y	Rwanda Education NGO Coordination Platform (2013)
	Teacher's wage	5	teachers	540'000	RWF/y	4'154	USD/y	
	Maintenance cost of school					1'154	USD/y	2.5% of Investment
					L - Total	**5'998**	**USD/y**	-10%
					C - Total	**6'665**	**USD/y**	
					H - Total	**7'998**	**USD/y**	+10%

Table 12 : Costs related to project planning and management

Type	Description	Number	Units	Unit cost	Units	total cost	Units	Comment
Investment cost	Relocation costs	43	hh	50	USD/hh	2150	USD	Hypothesis : 20 USD/hh
	Community work - Umuganda					31'923	USD	
	Initial planning cost by administration	440	man-day	4'800	RWF/day	3'249	USD	4800 RWF per man-day (post sec. educ. wage, wage indic. survey 2012), 440 man-days (2 full time)
					L - Total	**32'890**	**USD**	-20%
					C - Total	**41'113**	**USD**	
					H - Total	**49'336**	**USD**	+20%
Operation cost	Monitoring and capacity building	220	man-day	4'800	RWF/day	1'625	USD/y	330 man-days per year (1 full time)
					L - Total	**1'300**	**USD/y**	-20%
					C - Total	**1'625**	**USD/y**	
					H - Total	**1'950**	**USD/y**	+20%

4. Monetary evaluation of the project's benefits

Estimating the monetary value of the benefits of the Rubaya demonstration project constitutes one of the most important task of the CBA. On the one hand, assessing monetary values requires the adoption of hypotheses in order to transfer prices, wage levels and rate of return from similar (yet different) situations. On the other hand, capturing the incremental benefit due to the project also requires to make a hypothesis on the situation without the project. Obviously, the availability and quality of information on the project and its benefits constitute a crucial issue for the accuracy of the benefits estimates. Interviewing the beneficiaries and collecting local data allow to determine the willingness to pay of the beneficiaries for the benefits. In the case of the Rubaya demonstration project, the availability of data was rather good since two previous data collections have already been undertaken. However, the quality and veracity of this information remains at stake since its suffers from apparent contradiction (e.g. concerning the farming and terraced areas or the number of schoolchildren) and inaccuracies (e.g. concerning the cost of terracing and caring of cows). Accordingly, we set confidence intervals for each benefit estimates. These margins of errors result from the use of different valuation methodologies, transfer sources or hypothesis.

4.1 Farming

The project leads to an increase in the production of crops by the villages' inhabitants. This increase is due to the lower impact of soil erosion thanks to the terraces and the use of manure that increases the soil fertility. Without the project, the Rubaya site was characterized by declining soil fertility and land degradation, with inappropriate farming techniques around villages, especially on steep slopes with increased soil erosion. Other factors might also have been part of the story. However, we focus here only on the direct contribution of the project on agricultural productivity.

The loss of production due to erosion appears gradually over time while the impact of the use of manure appears in the short term. Note that the project did not increase significantly the area of cultivated land for the beneficiaries.

In order to estimate these two benefits, we proceed in two steps:

- First, using regional data on yields, prices and production cost as well as the information collected from the beneficiaries, we estimated the total value added of farming produced by the beneficiaries (see table 13).
- Second, using evidence based on Rwanda case studies, the additional value added due to terracing and the increased use of manure is estimated.

The actual value added from farming activities has been estimated in Rubaya at 13'162 USD/y. The yields have been collected locally and compared to the regional average. In Rubaya, yields remain lower in comparison to the Northern region. Costs (mainly due to the use of fertilisers) have been estimated on the basis of the interviews. A 10% loss (due to the use of seeds for the next production and various inefficiencies) is taken into consideration. Own consumption has been evaluated at its opportunity cost, which is equal to the market price of crops. Since yields and prices remain uncertain, we built a 20% confidence interval on yield and 10% on price. This lead to a value added from agriculture production lying between 9'000 USD/y and 19'000 USD/y.

Table 13 : Value added from farming activities

Crops	area (ha)	Yield (kg/ha/y)	Price (RWF/kg)	Turnover (RWF/y)	Cost (RWF/y)	% losses	VA (RWF)	VA (USD)
Bean	9.1	1'100	350	3'516'513	114'900	0.9	2'115'388	3'254
Potatoes	1.5	13'000	220	4'353'778	114'745	0.9	3'743'723	5'760
Wheat	3.0	2'200	350	2'344'342	128'925	0.9	1'717'383	2'642
Maize	1.5	3'000	270	1'233'063	85'950	0.9	978'915	1'506
						TOTAL	**8'555'409**	**13'162**

Note that the labour of the beneficiaries is not accounted for in the costs since we estimate the value added, i.e. the income that farming generates for the households (in exchange of their work).

A large body of literature is available on the effect of soil conservation techniques (such as terraces), irrigation and the use of manure. Evidences are also available for the region (see Corbeelsetal. 2014; Sileshi G et al. 2009; Telles et al., 2011; Atampugre, 2014; Rusinamhodzi et al. 2011) and for Rwanda (Bizoza and De Graaff, 2010; Siaz et al. 2016 Bizimana, 2011; REMA, 2014; Bosco et al, 2016; Clay et al., 1996; UNEP, UNDP and REMA; 2006).

Regarding terracing, as stated by Dorren and Rey, many scientists, soil conservation services and related institutions (e.g. USDA, 1980; AAFC, 1999; FAO, 2000; FFTC, 2004; GPA, 2004) agree that terracing reduces runoff and soil loss due to water erosion, showing that terracing makes it possible to reduce soil losses by half, independently of the used cultivation system. Chow et al. (1999) observed dramatic decreases in soil loss, from an average of 20 tons per hectare, to less than one ton per hectare, by terracing sloping fields in combination with the construction of grassed waterways and contour planting of potatoes. Runoff was reduced by as much as 25% of the total growing season rainfall, making it more available to the crop. One of the most reliable estimates of the annual yield loss due to soil erosion in Rwanda is provided by the World Bank's LWH (Land Husbandry, Water Harvesting and Hillside Irrigation) Project Appraisal (2009) documents. Accordingly, we consider that terraces (57% of the total farming area) avoid a 1.5% to 3% loss of the annual agricultural production[2].

The estimated benefits of terracing range from 3878 USD per year (75.5 millions RWF over 30 years) using a 1.5% loss per year and the low estimates of the farming value added to 6585 USD per year (128.4 millions RWF over 30 years) using a 3% loss per year and the high estimates of the farming added value. Such estimates are consistent with other evidence available in the literature[3].

According to Sileshi et al. 2009, the use of manure in sufficient quantity and on a regular basis might double the yield in a majority of cases. Interviews made in Rubaya confirm that, for beans, the annual yield (the quantity produced per ha) double (+100%) comparing to the situation when a lower quantity of manure was available. However, as the impact of fertilisers varies from case to case and might also capture the consequences of avoided erosion and better water management, we consider that between 30% to 50% of the added value of the farming activities would not have been possible without the additional manure application provided by the project. The estimated benefit varies from 3’600 USD/y using the low estimates of the farming added value to 7’800 USD per year using the highest estimates of the farming added value.

The annual benefits of terracing and manure application are presented in table 14. Agriculture is thus more productive leading to more income and jobs creation in the village. Note however that the benefit of terracing grows from year to year meaning that the soil fertility decline is measured on a compounding basis. The benefit of manure application is constant over time.

Table 14 : Average benefit per year due to terracing and manure application

	USD/y	USD/y/ha
Low value	6'571	432
Central value	9'718	638
High value	16'297	1'071

4.2 Livestock

The distribution of cows allows to produce milk, calves and meat. Interviewing the households, we discovered that none of them had a cow before the project and none of them consider that possessing

[2] Without terracing, the economic loss due to erosion will thus growth year after year. Using a 2.25% annual loss lead thus to complete vanishing of farming after 30 years.

[3] Branca et al. (2011) and Saiz et al. (2016) estimates the yield’s increase due to terracing at + 20% to + 25%. This is equal to the avoid cumulated loss after 6 to 8 years if no terracing is done.

a cow would have happened without the project. In other words, the without-the-project situation would be the total absence of cows in the village.

86 cows have been distributed: half of them (43) to the residents of the village and 43 to poor households living in the surrounding areas. The benefit provided by the 86 cows has been estimated since all of them has been financed by the project. Note that the project distributed cows to the surrounding population (whose poverty was severe) in order to have enough organic waste to feed up the biogas production system. The condition was that the cows should be kept in the common herds within the village.

The milk production is estimated by multiplying the number of cows (86) by the average milk production per cow (on average 5 litres per day) during the lactation period (180 days/cow/y). According to observations made in Rubaya and the existing evidence (IFRC, 2015; MINAGRI, 2009), around 900 litres of milk are thus produced per cow per year. Production loss (due to sick cows and accident) are estimated at 5%. In Rubaya, caring cows cost around 3000 RWF per month[4] (excluding labour cost) and the producers price for milk is 140 RWF/l[5]. The income from milk production is thus estimated at 11'900 USD per year (margin of error +/-20%). The benefit of the own consumption of milk has been evaluated at the market price of milk. This is a lower benchmark since no milk would be consumed if it has less value for the consumer than its market price (which represents thus the opportunity costs of own consumption), which is equal to its market price (as we did for crops). We consider that only 50% of the milk production was available the first year and 75% the second year.

A cow lives for 10 years, its meat might then be sold or eaten (so that the meat of 8-9 cows are on average available each year after 10 years). The value of meat is estimated at 1800 RWF/kg (250 Kg of meat per animal, 10% loss is also considered) leading to around 5'300 USD/y on average (margin of error +/-20%). We consider that the benefit related to meat production starts after 10 years.

A cow produces also calves. Since the beginning of the project (6 years), 76 calves have been produced by the 43 cows living in the village. We consider that the 43 cows distributed in the surrounding produced an identical number of calves. It is considered that 50% of calves are female. Most of the female calves are conserved by the beneficiaries in order to replace the old cows (on average 8-9 per year). We consider, on the basis on MINAGRI (2008), that some cows died (8% of death rate for calves and 2% for adult cattle). The calves not kept by their owner (around 15 male calves and 7 female calves per year) in the village are given to poor people in the surroundings. The market value of these animals is estimated at 250 USD/animal. Based on the previous information, the annual implicit income from calves lies around 5'500 USD/y (margin of error +/-20%).

Overall, the annual benefit related to the distribution of cows is presented in table 15. It contributes to the increase of income and the creation of jobs in the village. Note that the livestock also produce manure, the benefit of which is captured in section 4.1 (increasing farming yield).

Table 15 : Average benefit per year due to livestock

	Total (RWF/y)	Total (USD/y)
Low value	11'378'960	17'506
Central value	14'223'700	21'883
High value	17'068'440	26'259

4.3 Water and sanitation

The water and sanitation domain covers 3 benefits resulting from the improved access to sanitation and water source: productivity gains (lower number of loss of work days), reduction in health care costs and time savings.

[4] This cost is low (40%-60%) compared to what is found in the literature. This is explained by the fact that no fodder is bought for the cows. The fodder is taken for free in the nature and from the grasses grown for this purpose.

[5] The price of milk for producer in Rubaya is low compared to regional average (200-220 RWF/l), the low price of milk is explained by the margin of the vendors who buy the milk in the village and transport it to the market places. The village is indeed isolated and transport to and from the village remains costly.

The many analysis carried out under the auspices of the WHO have developed a large body of evidence on the benefit of a better access to water and sanitation. More particularly, Hutton et al. (2007) provides estimates for low-income households. Table 16 presents the benefits of a better access to water and sanitation per beneficiary as estimated by Hutton et al. (2007) for the East-African region. The benefits per beneficiary are presented for universal access as well as for the fulfilment of MDG target (halving the proportion of people who do not have access to improved water or basic sanitation between 1990 and 2015). Table 17 presents the benefits of an improved access to water only. Many analyses (CBA and Cost of environmental damages studies) rely on the WHO estimates and protocol.

Table 16 : Benefit of better access to water&sanitation

	MDG target* Benefit per beneficiary (USD/y)	Universal access Benefit per beneficiary (USD/y)
Total economic benefit, composed of:	42	48
Productivity gain	2%	3%
Reduction in health care costs	8%	10%
Time saving	90%	87%

Source : Hutton et al. (2007)

Table 17 : Benefit of better access to water

	MDG target* Benefit per beneficiary (USD/y)	Universal access Benefit per beneficiary (USD/y)
Total economic benefit, composed of:	6.5	9.0
Productivity gain	17%	21%
Reduction in health care costs	20%	24%
Time saving	63%	55%

Source : Hutton et al. (2007)

The project guarantees that all village residents have an improved access to covered private pit latrine and improved access to water. Considering that about 40% of the village's population would have benefited from improved access to sanitation and water even without the project (national average in rural areas), we can estimate the incremental benefit provided to village residents. Note that we correct the benefits estimated by Hutton et al. considering the GDP per head (WB Atlas method) increase between 2007 and 2010 (+38%).

Non-residents of the village also benefit from the increased availability of water. It is estimated that around 2480 m^3 of water per year are consumed by non-residents of the village (so that around 84 households – 402 people benefit from an improved access to water). Considering again that 40% of the non-resident would have access to an improved water source even without the project, we can estimate the incremental benefit provided to non-residents.

The estimated benefit of production gain and the reduction in health care cost is presented in table 18. It amounts to 2'450 USD/y. If MDG targets are considered, the overall benefit would equal to 1710 USD/y (lower estimates).

Table 18 : Benefit of production gain and the reduction in health care cost of an improved access to water and sanitation for resident and improved access to water for non-residents

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
Residents : Health and economic benefits with universal access to W&S	124	Indiv.	8.9	USD/ben/y	719'139	1'106
Non-residents : Health and economic benefits with universal access to W	241	Indiv.	5.6	USD/ben/y	876'136	1'348
				Total	**1'595'275**	**2'454**

The project generates also time savings for the residents as the travel distance to water sources is considerably shortened thanks to the project. Time gains have been estimated by the village residents at 175 minutes per day per household. The related benefit might be estimated by considering the opportunity cost of time (50%[6] of the prevailing unskilled wage rates: 1200 RWF/day). The ratio of 50% is commonly used as a rule of thumb. Its validity has however been recently confirmed by Cock et al. (2015).

Note that the Hutton et al. (2007) estimates offer an alternative estimate of the benefit[7] (see table 19). The latter is also used to estimate the time saving of non-residents. Again, we consider that, without the project, 40% of the residents and non-residents would have benefited from similar time savings anyway.

Table 19 : Benefit of time saving of an improved access to water and sanitation for resident and improved access to water for non-residents

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
Residents : Time saving benefits with universal access to W&S	45777	hour/y	75	RWF/h	3'433'281	5'282
Alternative estimate using Hutton et al. (2007)	124	Indiv.	57	USD/pers	4'646'060	7'148
Non-residents : Time saving benefits with universal access to W	241	Indiv.	6.8	USD/pers	1'067'528	1'642
				Total	**4'500'810**	**6'924**

Finally, water is sold to the residents and non-residents leading to an income for the village cooperative. Residents pay a lump sum per month (500 RWF/month allowing to consume 80 litres per day per household), non-residents pay 1 RWF/litre. Without the project, no water would have been sold.

Table 20 : Income from water selling

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
Water consumption - Income from resident	1241	m3/y	208.33	RWF/m3	258'542	398
Water consumption - Income from non-resident	2482	m3/y	1000.00	RWF/m3	2'482'000	3818
				Total	**2'740'542**	**4'216**

4.4 Energy and forest

The domain "energy and forest" covers 4 benefits : health and economic benefits (lower health costs, gain of working and education days) due to the better indoor air quality, time gain related to the lower necessity to collect wood, lower pressure on the forest ecosystem and the reduction of greenhouse gases (GHG) emissions by the use of biogas (without the project, GHG emission resulting from the decomposition of organic waste would have happened anyway and emissions from the burning of wood would have occurred). Even if small and at the global scale, the mitigation of GHG emissions has to be included in the project. If not, its efficiency would be slightly lower compared to evaluations that include climate benefit. However, it might be difficult to valorise the mitigation of GHG later if they are ignored or put aside by the present CBA.

As for the benefits of water and sanitation, reference values have also been produced by the WHO (see Hutton et al., 2006). The estimated benefit per beneficiary resulting from the use of biogas (instead of wood) by the poor households for cooking has therefore been transferred to the Rubaya village. Table 21 presents the unit value of the benefit and its composition for the East African region reflecting a reduction by 50% of the population without access to a cleaner fuel and an improved stove.

[6] The ratio of 50% is used by Hutton et al. (2007) for estimating the opportunity cost of time.

[7] The highest value is explained by the fact that Hutton et al (2007) includes also the time saving of improved sanitation.

Since the whole population of the village has access to biogas, the WHO value might underestimate the benefits. However, wood is still used for cooking in Rubaya since biogas is not always available and provides at times not enough heat, e.g. to cook beans.

Fuel cost savings have not been accounted for, since the beneficiaries declare that they would not buy wood anyway if the project was not realized. They would only collect wood directly in the surrounding forest since their income was too low to buy wood. Cooking time saving has also been left aside since the beneficiaries questioned its relevance as a benefit. This might not be correct for each household but we prefer to avoid to consider a benefit if this benefit has not been explicitly mentioned by the beneficiaries.

Table 21 : Benefit of a 50% reduction of the population without access to a cleaner fuel and an improved stove

	Values
Benefit per beneficiary:	**68 USD/beneficiary**
composed of:	
Fuel cost saving	2.5%
Health-system cost savings	0.2%
Patient-cost savings	0.0%
Fuel-collection time savings	52.4%
Cooking-times saving	17.0%
Sickness time avoided	1.2%
Deaths averted	11.0%
Avoided deforestation (local)	10.9%
Reduction in CO2emissions	4.6%
Reduction in CH4 emissions	0.1%

For transferring the benefits, we also adapted the value to year 2010 according to the growth rate of GDP per head (WB Atlas method) between 2007 et 2010 (+38%). Without the project, no resident of the village would benefit from biogas. In Rwanda, the use of biogas remains rare and the development of the necessary infrastructure (digesters) necessitates public support.

The estimated economic and health benefits are presented in table 22, and the time saving benefits figure in table 23. Finally, table 24 and 25 present the benefits related to avoiding deforestation and GHG emission reduction. For health, an alternative estimate, based on 80% reduction in the number of disability adjusted life years (DALYS) and a value of DALYS corresponding to 50% of the average rural wage, is also provided. For time saving resulting from wood collection, an alternative estimate based on field data (household estimated that they saved 2 hours per day) is also proposed. As for time savings for water collection, we applied an opportunity cost of time equal to 50% of the farming wage. The difference between the 2 values appear to be very large in this case. We therefore consider the conservative alternative estimate, which relies on field data. The estimate based on WHO value is however conserved in the sensitivity analysis. Deforestation costs are based on the cost of remediation (planting trees). It is thus a conservative value which does not account for losses of non-wood products and damages to biodiversity.

Evidence on the total economic value of Rwanda Gishwati Forest reserves are available in UNEP-UNDP (2006). They more particularly demonstrate that forest provides in Rwanda important indirect benefits as maintaining soil quality, limiting erosion, stabilising hillsides and modulated seasonal flooding. Forest also provides medicine, wild fruits and food and animals. They also constitute tourist attraction.

Table 22 : Health and economic benefit from the use of biogas

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
WHO unit value	207	Indiv.	11.7	USD/indiv.	4'900'388	2'432
Alternative estimate : DALYS averted	7	DALYS/y	181'714	RWF/indiv.	1'355'836	2'086
				Total	**4'900'388**	**2'432**

Table 23 : Time saving benefit from the use of biogas

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
Time saving benefits for fuel wood collection	207	Indiv.	49	USD/indiv.	6'665'297	10'254
Alternative estimate : Time saving benefits from fuel wood collection	31390	hour/y	75	RWF/hour	2'354'250	3'622
Time saving from cooking	207	Indiv.	16.1	USD/indiv.	(2165533)	(3332)
				Total	**2'354'250**	**3'622**

Table 24 : Benefit of avoided deforestation due to the use of biogas

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
Avoided deforestation	207	Indiv.	10	USD/indiv.	1'390'899	2'140
				Total	**1'390'899**	**2'140**

For GHG reduction, Hutton et al (2007) considers CO_2 and CH_4 emission reductions and uses a value of 4 USD per ton of CO_2. We also provide two alternative estimates in table 25, based on 10 USD per ton of CO_2 and 38 USD per ton of CO_2. The latter corresponds to the social cost of carbon (SCC) estimated by US IWG (2013), which is the marginal global net damage cost of an additional ton of carbon emitted today, aggregated over time and discounted back to the present day. The SCC can therefore be interpreted as the marginal benefit of reducing emissions by one ton. This reflects the actual expected damage costs of greenhouse gas emissions, rather than the traded price or the marginal abatement costs, both of which do not reflect the actual damage and loss caused by climate change.

Table 25 : Benefit of GHG emission reduction due to the use of biogas

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
GHG avoided, CO2 price = 4 USD/t	207	Indiv.	4	USD/indiv.	600'772	924
Alternative 1 with CO2 price = 10 USD/t					1'501'930	2'311
Alternative 2 with CO2 price = 38 USD/t					5'707'333	8'781
				Total	**1'501'930**	**2'311**

4.5 Education

The development of the educational services in the village generates two benefits. First, it contributed to the increase of the human capital stock and thus raises income level. According to Millennium Development Goals, the access to education is a crucial factor for decreasing illiteracy and take people out of poverty, Second, the development of the educational services reduces the cost of getting education, decreasing the distance to school and thus the time constraint of education.

In 2017, when we visited the village, primary education (from P1 to P6) was provided to 252 children (4 classes). A total of 122 children are living in the village; 5 teachers are working in the village school. Note that more than 600 children used to come to this school at the beginning of the project. The decrease is recent and is due to the opening of another primary school in the region.

Providing education to children has a strong incidence on the productivity of labour, which translates on higher economic growth rates. Such medium to long-term effect is difficult to measure at the site level only a few years after the project starts. Note that the quality of the education is also at stake for ensuring such benefit.

International institutions (such as the World bank) and NGOs (see for example the Copenhagen consensus center) have provided a large body of recent evidences on the social rate of return of education. The social rates of return indicate the economic benefit provided by education considering the full cost of schooling, rather than just what the individual pays for his or her education. Psacharopoulos and Patrinos (2004) realized a comparative analysis of existing social rates of return of education and established a rate of 15.9% in the case of primary education in Africa. Such value is confirmed by Psacharopoulos (2014). Bloom et al. (2006) estimate a rate of return of 18.9%. On the basis of household surveys, Peet et Fink (2015) indicates that heterogeneity of the estimates in developing countries is large. They indicate an average value of 9.2% for Africa. Based on the previous findings, we will provide estimates based on a 15% rate of return to primary education, using 9% and 20% as lower and upper benchmarks (sensitivity analysis).

The benefit is calculated by multiplying the total cost of education (central estimates) over the life span of the project (20 years) by the rate of return to primary education. The benefit is then distributed equally over time. Table 26) present the results. Without the project, investment in education would have been made anyway so that the total amount should not be attributed to the project. According to national statistics, 70% of the children of the lowest quintile have access to education (see Ministry of Education). We thus consider that the project will bring all children to school, adding 30% of the total benefit.

The estimate is based on the investment costs so that the whole benefit is captured independently of the place of living of the schoolchildren.

Table 26 : Rate of return of primary education

	Present value of the cost of education (20 years)	Unit	Rate of return (primary education, Africa)	Total (RWF/y)	Total (USD/y)
Higher attendance to school	124'338	USD	9% (lower benchmark), weight 0.3	1'321'407	2'033
			15%, weight 0.3	1'394'145	2'145
			20% (upper benchmark), weight 0.3	1'454'760	2'238

The shortened distance to school also reduce the traveling time for most of the children. For the village children, the time saving has been evaluated to 170 minutes per day per children (on the basis on responses of the residents). For children living outside the village, the time saving has been evaluated at 120 minutes per day per children. The opportunity cost of time is equal to 30% of the rural wage. This is less than the opportunity cost of time use in the case of time saving for water and wood collection, since the benefit concern exclusively children, whose labour productivity is on average lower. The results are presented in table 27. The time saving amount to 12'000 USD/y (+/- 20 margin of errors).

Table 27 : Time saving benefit due to the proximity of school

	Quantitative frame	units	Monetary frame	units	Total (RWF/y)	Total (USD/y)
For children from the village	73’100	hour/y	60	RWF/hour	4'386'000	6'748
For children from the surroundings	56’760	hour/y	60	RWF/hour	3'405'600	5'239
				Total	**7'791'600**	**11'987**

4.6 Better housing

The discussions with the beneficiaries showed that one of the most important benefits of the project is the provision of decent houses. Indeed, without the project, the houses of the beneficiary households would be smaller and of (much) lower quality (no bathroom, no separate kitchen, lower quality insulation). They indicated that the houses make them feel more secure and strengthen the stability of their living conditions. It is therefore important to stress once again that the houses are the project's most important outcome for the beneficiaries.

In order to value the benefit of the better housing conditions offered by the project, we try to compare the value of the house in the village to the average house value in the region[8].

Actually, some houses in the village are rented by initial beneficiaries to new residents. The rent is around 35’000 RWF/month while traditional habitation in the surroundings are rented around 7’000 RWF per month. The difference between these rents (35’000 – 7’000 = 28’000 RWF/month) is a proxy for capturing the benefit of the houses' attributes. As far as the differences in rent might also be attributed to other features of the village (presence of a school, of water sources, of sanitation, accessibility, etc.), the proposed value (around 18’000 USD per year, table 28) might slightly overestimate the benefit of better housing.

Therefore, we built an alternative estimate considering the rent that would provide a 6.5% rate of return on the initial investment (6.5% is equal to the market interest rate and is considered as the opportunity cost of capital), considering an additional 2.5% for covering maintenance cost (as considered in the costs). The calculated rent is equal to 36’152 RWF per month (289’868 RWF per year, see table 28), which is close to the initial value. We keep the first estimate (since it is based on field observations) and consider a +/- 20% margin of error.

Table 28 : Benefit of better housing

	Quantitative frame	units	Value	Units	Total (RWF/y)	Total (USD/y)
Benefit from better housing	43	houses	276’000	RWF/house/y	11'868'000	18'258
Alternative estimate based on 6.5% rate of return on the inv.	43	houses	289’868	RWF/house/y	12'464'311	19'176
				Total	**11'868'000**	**18'258**

4.7 Exposure to natural disaster

Without the project, many households would be still living on steep slopes, categorized as high risk zones. Therefore, they would remain highly vulnerable to landslides or other environmental disasters related to high slopes. By moving the households to less steep areas, the project therefore reduces the exposure to risk of natural disaster. The consequences of landslides have been stated by the households. Using market price, the resulting avoided damages per year are estimated (see table 29).

[8] Ideally, some contingent choice survey could be done.

Table 29 : Benefit of reduce exposure to natural disasters (landslide)

	Quantitative frame	Unit	Monetary frame	Unit	RWF/y	USD/y
Houses destroyed	4	unit/y	109	USD/unit	282’609	435
Sheep killed	4	unit/y	21.7	USD/unit	51’837	80
Goat killed	5	unit/y	21.7	USD/unit	70’687	109
Beans	153	kg/y	0.58	USD/kg	57’806	89
Sorghum	110	kg/y	0.36	USD/kg	25’918	40
Wheat	1200	kg/y	0.43	USD/kg	339’300	522
Other crops	1988	kg/y	0.36	USD/kg	468’422	721
				Total	**1’296’582**	**1995**

In order to test the previous values, an alternative approach has also been used (see Paul Watkiss Associates, 2016). In a study on the total economic value of the Mukura Forest in Rwanda, respondents were asked to value a reduction in the risk of landslides and flooding from severe weather events. This reflects a proxy willingness to pay value for avoiding these damages. The benefits derived from landslides and flood control by the Mukura Forest were estimated at 84’506 USD, or 7 USD per person per year (Arcos, 2014). The total benefit is estimated at 1450 USD/y.

5. CBA results

5.1 Aggregating and discounting the costs and benefits

Table 30 presents all the benefits of the project (central estimates) once aggregated and discounted over the time span of the project. As indicated in section 1.3, 4 discount rates are considered (3%, 6%, 10% and 13%) over 2 periods (20 and 30 years). Table 31 presents the costs of the project (central estimates). The relative importance of each domain is also presented.

Table 30 shows that the total benefit of the project amounts to 1,17 million USD over 30 years (6% discount rate) and the main benefits are related to livestock (21.5%) and better housing (21.4%). Non-residents of the village also profit from the project (cows, access to water and education, reduced GHG). These benefits represent 25% of the total amount (considering a 30-year period and a 6% discount rate).

The “direct” and “immediate” additional income (or own consumption) gain for the beneficiary households (additional added value from farming, from milk and meat production) provided by the project represents around 26% of the total benefit of the project.

Table 30 : Aggregated and discounted benefits (USD)

	Discount rates	3%		6%		10%		13%	
20 years	Farming	131'300	10.4%	97'755	10.1%	69'311	9.8%	55'353	9.6%
	Livestock	270'674	21.4%	201'930	20.9%	143'491	20.3%	114'731	19.8%
	Water and Sanitation	202'256	16.0%	155'931	16.1%	115'740	16.4%	95'500	16.5%
	Energy and forest	156'279	12.3%	120'484	12.5%	89'430	12.6%	73'791	12.8%
	Housing	271'640	21.5%	209'423	21.7%	155'445	22.0%	128'261	22.2%
	Education	208'582	16.5%	160'808	16.6%	119'360	16.9%	98'487	17.0%
	Exposure to natural disasters	25'631	2.0%	19'760	2.0%	14'667	2.1%	12'102	2.1%
	TOTAL	**1'266'362**		**966'093**		**707'443**		**578'225**	
30 years	Farming	182'736	10.8%	122'748	10.4%	79'257	10.0%	60'481	9.7%
	Livestock	374'025	22.1%	252'149	21.5%	163'477	20.7%	125'036	20.1%
	Water and Sanitation	266'464	15.7%	187'130	15.9%	128'157	16.2%	101'902	16.4%
	Energy and forest	205'891	12.1%	144'591	12.3%	99'024	12.5%	78'737	12.7%
	Housing	357'874	21.1%	251'325	21.4%	172'121	21.8%	136'859	22.0%
	Education	274'798	16.2%	192'983	16.4%	132'165	16.7%	105'089	16.9%
	Exposure to natural disasters	33'767	2.0%	23'714	2.0%	16'241	2.1%	12'913	2.1%
	TOTAL	**1'695'556**		**1'174'639**		**790'443**		**621'018**	

The total cost of the project amounts to 0.87 million USD over 30 years using a 6% discount rate (table 31). The most important costs are related to "energy&forest" (25.2%), as well as "water&sanitation" (21.2%).

Table 31 : Aggregated and discounted cost (USD)

	Discount rates	3%		6%		10%		13%	
20 years	Farming	26'993	3.0%	26'088	3.1%	25'305	3.2%	24'909	3.2%
	Livestock	69'109	7.7%	68'925	8.2%	68'766	8.7%	68'686	8.9%
	Water and Sanitation	205'031	22.9%	201'801	24.0%	199'008	25.1%	197'598	25.7%
	Energy and forest	249'057	27.8%	229'892	27.3%	213'314	26.9%	204'952	26.7%
	Housing	141'483	15.8%	132'745	15.8%	125'187	15.8%	121'375	15.8%
	Education	110'328	12.3%	99'933	11.9%	89'838	11.3%	84'162	11.0%
	Project management	93'482	10.4%	81'471	9.7%	71'081	9.0%	65'840	8.6%
	TOTAL	**895'484**	**100%**	**840'856**	**100%**	**792'498**	**100%**	**767'522**	**100%**
30 years	Farming	28'247	2.9%	26'696	2.8%	25'547	2.7%	25'034	2.6%
	Livestock	69'363	7.2%	69'049	7.2%	68'815	7.2%	68'711	7.1%
	Water and Sanitation	209'502	21.8%	203'971	21.2%	199'872	20.8%	198'044	20.6%
	Energy and forest	275'584	28.6%	242'767	25.2%	218'444	22.7%	207'596	21.6%
	Housing	153'577	16.0%	138'615	14.4%	127'526	13.3%	122'580	12.7%
	Education	115'778	12.0%	102'578	10.7%	90'892	9.4%	84'705	8.8%
	Project management	110'107	11.4%	89'539	9.3%	74'296	7.7%	67'498	7.0%
	TOTAL	**962'157**	**100%**	**873'215**	**91%**	**805'392**	**84%**	**774'170**	**80%**

5.2 CBA results

Table 32 presents the net present values of the project, the benefit to cost ratios (B/C), the rates of return (RoR), the internal rates of return (IRR) and the payback periods of the project. The results presented rely on the central estimates of the benefits and costs. **The results indicate that the project is efficient when 6% and 3% discount rates are considered, over 15, 20 and 30 year periods. The project is also close to efficiency using a 10% discount rate over 30 years.** Furthermore, not all benefits have been included since no monetary estimate of the benefits of social cohesion, which are described as important by the beneficiary, could be determined.

Considering the highest values for each parameter (i.e. a 6% discount rate and 20 and 30 year periods), the project efficiency is high, leading to benefits surpassing the costs by 15% to 35%. The rate of return also appears to be high (20% and 47%), way higher than any return rate one could obtain through private banking. The internal rate of return over a 30-year period stands at 8.9%, above the 7.7% rate of the 20-year span. Finally, the payback period is of close to 15 years with a 6% discount rate.

All these results prove the project efficiency is high if a sustainable, social and long-term perspective is adopted. However, (private) investors whose emphasis is on short term financial returns only would be unlikely to use their own funds to build projects similar to the Rubaya demonstration project on the basis of the lack of financial benefits to them. This gap between national economic benefits and private sector financial benefits is a key rationale for mobilising public sector funds (government and donor) to fund the scaling up of the village.

Table 32 : CBA results (based on central estimates)

Indicators	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	145'368	370'879	733'398
	6%	-9'679	125'161	301'311
	10%	-154'671	-85'055	-14'949
	13%	-232'438	-189'297	-153'152
B/C	3%	1.17	1.41	1.76
	6%	0.99	1.15	1.35
	10%	0.80	0.89	0.98
	13%	0.69	0.75	0.80
RoR	3%	23%	58%	115%
	6%	-2%	20%	47%
	10%	-24%	-13%	-2%
	13%	-36%	-30%	-24%
IRR		5.8%	7.7%	8.9%
Payback period	3%	12-13 years		
	6%	15-16 years		
	10%	30-31 years		
	13%	>31 years		

Table 33 provides further details on the C/B ratios by domain. It shows that farming, livestock, education and housing provide more benefit than costs.

For livestock, our results are close to those of the CBA Rwanda Red Cross Livestock Rotation Programme IFRC (2016). For education, they are also in line with actual research.

For “water&sanitation” and “energy&forest”, our results are however far below the B/C ratios of the WHO (Hutton et al, 2007a et 2007b), even if the authors indicate that their estimates present a strong heterogeneity. Our results might be explained by the high costs of the interventions (mainly water reservoirs and biogas-digesters) in these two domains compared to those considered by the WHO. For example, the investment cost per capita for water supply (house connection) is set at 12 USD by the WHO, whereas the project's investment cost per capita for "water&sanitation" is around 220 USD. The difference is striking. It might be explained by specific local conditions, unexploited scale economies or, alternatively, the possibility that some costs were not considered by the WHO estimates.

Table 33 : C/B ratios by domain

B/C ratios	3% discount rate		6% discount rate	
	20 years	30 years	20 years	30 years
Farming	4.6	5.7	3.4	4.1
Livestock	3.9	4.8	2.6	3.3
Water & sanitation	1.0	1.1	0.7	0.8
Energy & forest	0.6	0.7	0.5	0.5
Education	2.3	2.7	1.9	2.2
Housing	1.5	1.8	1.2	1.4

5.3 Sensitivity analysis

The aim of the sensitivity analysis is to estimate upper and lower benchmarks of benefits and costs. These estimates have been built by considering alternative methodologies and hypothesis. When not possible, we postulate +/- 20% margin of errors.

The results presented in section 5.2 are based on the central estimates. These remain the most reliable in our opinion. They are conservative estimates. In case of uncertainties concerning one parameter, we always favour values that tend to underestimate the benefits. Similarly, we tend to avoid counting benefits that would have occurred without the project. On the cost side, even if the uncertainties are smaller, we proceed in the opposite direction, using values that might lead to an overestimate of costs.

Consequently, we test the sensitivity of our results by postulating higher benefits (upper estimates of benefits and central estimate of costs) in one case and lower cost in another (lower estimates of the costs and central estimate of benefits). The results are presented in table 34 and 35.

Table 34 : CBA results – sensitivity tests (based on higher benefits and central costs)

Indicators	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	444'928	749'153	1'238'234
	6%	242'027	**429'136**	**676'671**
	10%	34'276	128'192	222'772
	13%	-72'454	-14'254	34'509
B/C	3%	1.52	1.84	2.29
	6%	1.30	**1.51**	**1.77**
	10%	1.04	1.16	1.28
	13%	0.90	0.98	1.04
RoR	3%	70%	117%	194%
	6%	38%	**67%**	**106%**
	10%	5%	20%	35%
	13%	-11%	-2%	5%

Table 35 : CBA results – sensitivity tests (based on low costs and central benefits, USD)

Indicators	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	242'868	473'900	845'290
	6%	83'132	**221'273**	**401'733**
	10%	-66'346	4'975	76'796
	13%	-146'574	-102'377	-65'348
B/C	3%	1.32	1.60	1.99
	6%	1.11	**1.30**	**1.52**
	10%	0.90	1.01	1.11
	13%	0.78	0.85	0.90
RoR	3%	38%	74%	132%
	6%	13%	**35%**	**63%**
	10%	-10%	1%	12%
	13%	-23%	-16%	-10%

Both sensitivity tests confirm the results. They also demonstrate that the NPV could widely be underestimated by our conservative approach and that the project might also be efficient considering 10% discount rate.

We also test the opposite situation, i.e. overestimating the cost (using a central estimate of the benefits, table 36) or underestimating the benefit (using a central estimate of the costs, table 37). It shows that even if the project is less efficient, it remains nonetheless profitable in all cases using a 6% discount rate over 30 years.

Table 36 : CBA results – sensitivity tests (based on low benefits and central costs)

Indicators	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	-53'282	122'031	405'592
	6%	-165'687	**-58'022**	**85'392**
	10%	-278'975	-224'867	-170'039
	13%	-337'266	-303'739	-275'473
B/C	3%	0.94	1.14	1.42
	6%	0.80	**0.93**	**1.10**
	10%	0.64	0.72	0.79
	13%	0.56	0.60	0.64
RoR	3%	-8%	19%	64%
	6%	-26%	**-9%**	**13%**
	10%	-44%	-35%	-27%
	13%	-53%	-48%	-43%

The sensitivity test overall confirms our previous conclusion. The project has generated more benefits than costs (considering a 6% discount rate over 30 years). Applying 20% margins of error on the costs or benefits does not modify the previous conclusion. **These results provide decisive and strong arguments in favour of the project's extension and replication.**

Table 37 : CBA results – sensitivity tests (based on high costs and central benefits)

Indicators	Discount rates	15 years	20 years	30 years
NPV (in USD)	3%	44'906	264'896	618'545
	6%	-104'671	**26'868**	**198'708**
	10%	-244'368	-176'456	-108'066
	13%	-319'195	-277'110	-241'850
B/C	3%	1.05	1.26	1.57
	6%	0.89	**1.03**	**1.20**
	10%	0.72	0.80	0.88
	13%	0.62	0.68	0.72
RoR	3%	7%	41%	97%
	6%	-16%	**4%**	**31%**
	10%	-38%	-28%	-17%
	13%	-50%	-43%	-38%

5.4 Limitations of the analysis

The principal limitations of the analysis are the following.

First, we used data and information from field surveys that were undertaken by two different research teams. We cross-checked this information by interviewing stakeholder and project managers, as well as through field surveys in the Rubaya village. We also compared the figures (mainly costs) with the Rweru green village officials. However, the quality of the results clearly depends on the precision and understanding of the data. We have to recognise that some of these data were collected by another research team. The risk that we misinterpreted their meaning and thus wrongly assessed some costs or benefits therefore exists. We had also the feeling that some information that had been collected during the initial phase of the project had been lost later on since no monitoring process was in place.

Secondly, we quantify some environmental benefits using market proxies or so-called benefits transfers. Benefit transfer might lead to large transfer error rates (Shrestha et Loomis, 2001; Ready and Navrud, 2006) and results have thus to be interpreted with caution. We however had neither the time nor the resources to apply valuation technics based on surveys. In our opinion, it would have been relevant to apply a contingent choice at the start of the project. However, we are still confident with the accurateness of these benefit transfers and they seem in line with what officials and inhabitants have mentioned.

Finally, some benefits could not be estimated in monetary terms. First, the social benefit related to being a member of the supportive community was left aside even though the beneficiaries indicated that this was important to them and provided security and stability. Second, as explained in section 2, the Rubaya green village consists of several components (water, livestock, energy, farming, education, etc.), which interact with one another. For example, the proximity of water sources frees up time for working in the field or taking care of the cows. Similarly, the better health of the population strengthens the educational services provided inside the household. Parents have more time and better quality time to spend with their children leading to stronger togetherness in the village. This system effect aims at strengthening the sustainability of the economic development of the village. The quantitative analysis proposed by the CBA cannot account for such “system effects”. Furthermore, we did not include either the time saving benefits for reaching the farming area and for cooking, since these were not confirmed by the field visit.

Consequently, the overall benefit of the project might be larger than the NPV measured by the CBA suggests.

5.5 Success factor and improvement potential of the project

The CBA analysis provides results on the project’s efficiency. Such information constitutes a clear prerequisite for scaling up the model across Rwanda. However, the CBA analysis is above all a process that reveals a tremendous amount of qualitative information on the project's advantages and drawbacks.

We list here the most important elements concerning the success and potential improvement of the project.

The selection of beneficiaries constitutes a key issue. Indeed, the quality of life in the green village is higher than in the surrounding areas. Such differences may lead to jealousy and animosity between beneficiaries and non-beneficiaries. In the case of the Rubaya and Rweru Green villages, the selection process was successful in avoiding such outcomes. Indeed, beneficiary households were chosen by the local community on the basis of the poverty status and were not imposed from outside. It allows to select a relatively large proportion of extremely poor female-headed households. Furthermore, the project benefits have been extended to others beyond the targeted group (distribution of cows, access to school, water availability). Beneficiaries mentioned though that they faced some constraints during the transition phases (distance to relatives, distance to former farming areas which were still in production during the transition period).

The **creation of a community** was important not only for the people living in Rubaya but also for organizing the village and the related production. The creation of the cooperative, leaded by a woman at the time we visited the Rubaya village, strengthened the togetherness of the community and has constituted an essential factor for the caring of the common infrastructure, to manage conflicts and to provide security.

Capacity building efforts constitute a second key factor of the project’s success. Those efforts have raised the awareness of the beneficiaries and empowered them with the skills to work together as a community and to manage the project assets responsibly and sustainably. Furthermore, as expressed by Twesigye-Bakwatsa and Bizoza (2014), the training strengthens the collective mobilisation of the beneficiaries and the emphasis on common property and resource sharing arrangements. These have enabled mutual support so that the most vulnerable members are able to manage the facilities (e.g. biogas and water) and economic assets (cows managed in collective sheds) provided by the project.

The collaboration between key stakeholders and institutions early in the project design appear also very important. The project design team regularly consulted with the local authorities at the district and sector level during scoping activities, shared preliminary concepts and budget data with them, and held joint planning sessions with local technical and political leadership. By the time it was formally launched at community level in July 2008, the project was already “owned” by local authorities. Initial efforts to integrate in and align the project activities with local authorities’ activities secure also early understanding, interest and direct involvement in project activities by local authorities, thereby fostering ownership. The intersectoral coordination was clearly a key success factor since it would have been otherwise very difficult for one single institution to manage the green village.

In general, the **beneficiaries confirmed the success of the projec**t, which brings them out of poverty (table 38). They also confirmed that the actions taken in the farming and livestock domains were determinant factors for raising their income (table 39). The beneficiaries also mentioned that the housing quality improvement was the most important driver of benefits for them. In second place came water, sanitation and biogas, then milk production and terracing and finally access to school.

Table 38 : Project consequences on Poverty

	Before			After		
	Beneficiaries	**Non-beneficiaries of similar status and area**	**Non-beneficiaries of similar status only**	**Beneficiaries**	**Non-beneficiaries of similar status and area**	**Non-beneficiaries of similar status only**
Abject poverty	21.1%	29.6%	50%	2.6%	27.8%	38%
Very poor	60.5%	63%	50%	52.6%	53.7%	62%
Poor	18.4%	7.4%	0	44.7%	18.5%	0
Resourceful poor	No case					
Food rich						
Money rich						

Source: Twesigye-Bakwatsa C. and Bizoza A.R., 2014.

Table 39 : Source of additional income of the project's beneficiaries

	% of positive answer
Crop production increased so that household now have more for home consumption and surplus for sale.	57.9%
I now produce new crops which have higher demand and fetch higher prices	8.1%
I now have a lactating cow, so we are able to produce enough for consumption and sale	45.9%
I now belong to a cooperative that markets our produce and fetch better prices.	24.3%
I have since started business from where my income comes.	2.6%
I have since got a formal job from which my income comes	5.4%
There are more casual jobs/Wages from casual jobs	21.6%

Source: Twesigye-Bakwatsa C. and Bizoza A.R., 2014.

Analysing data and interviewing households also allow us to identify improvement possibilities.

- First, some cost figures appear to be higher than average (such as the price of cows, the investment costs for the waste and sanitation system, the house construction costs). However, this might be explained by particular circumstances and the topographic characteristic of Rubaya. Replicating the model should reduce these unit costs (scale economies might be possible).
- The access to the village remains difficult. This is costly for milk production, since transportation costs reduces the producer price by 30% (140 RWF per liter instead of 200 RWF/l). The cooperative is looking forward to one day purchasing a pick-up truck of its own to transport milk to the market, avoiding numerous accidents on one hand and gaining the ability to sell their milk at a much higher price due to easier market accessibility on the other. The cooperative also expressed the need to increase their income sources and revenues by developing a milk processing unit. However, their actual income does not allow them to get the technical and financial support to achieve this goal.
- The transition period might also be problematic for (some of) the households, since they still have to take care of their former farming land during a few months (if not they will lose one whole harvest), which might be far from the new home. This has been presented by households as a major problem in Rweru.

- The capacity to repair the biogas system might be difficult to find when technical aspects are involved. Furthermore, there are in Rubaya on average seven households for one facility and conflicts do arise over some households not providing dung from their cows for the biogas installation operation on a regular basis. The manager suggested that fewer households per biogas facility (e.g. 4 households) would reduce the number of disputes. In addition, should a breakdown of a facility occur, less people would be affected and it would be easier to assign them to other groups' facilities while waiting for the repairs to be done.
- The tree nursery products also encountered some difficulties. At least 30% of the trees planted were destroyed during construction of houses and roads, as they were planted in the pots too early. Many potential benefits from the tree nursery have not been identified and documented by this study, because the nursery was not operational in 2014 (as observed by Bakwatsa and Bizoza; 2014) and still not in 2017 (as we observed during the field visit) and records of its operations could not be obtained. This means that the investment and other costs associated with the tree nursery have no corresponding benefits yet. Nonetheless, it is important to observe that the aspect of tree planting received considerable attention at the beginning of the project, when the tree nursery was rehabilitated.
- Contrary to what was initially planned, the irrigation infrastructure (water for production) and solar energy infrastructure have not been fully implemented.
- A monitoring tool should be put in place. Such tool would facilitate the collection and selection of key data and the follow-up indicators. Such tools will be necessary for evaluating the project in the future. It would even better to design it in the form of a real-time impact evaluation, where costs and benefits would be monitored continuously, with possibilities for fine tuning (of the costs and benefits) throughout the time of project implementation.
- Finally, it could be interesting to conduct a cost-benefit analysis for the full-scale nation-wide project, which is based on location-specific information from the identified villages. Such analysis would provide a more representative picture (than the actual scaling up estimated based on 2 villages only) given the socio-economic and bio-physical diversity across the country. Such study would however be costly and requires time even if such cost might be small compare to the total investment.

Part III : Business plan and benefit of project scaling-up

1. Introduction

Initially, the project raised scepticism from different parties. The project was judged risky and lacked comparable precedents. Furthermore, the limited capacity for planning and implementation of the local communities required considerable help and efforts by a range of Government agencies including Ministry of Local Government (MINLAOC), Ministry of Agriculture (MINAGRI), Ministry of Natural Resources (MINIRENA), Ministry of Infrastructure (MININFRA), Rwanda Housing Authority (RHA) and the Gicumbi District. The CBA (see part II) proves that the project raises more benefits than its cost, even when using a strong conservative hypothesis for estimating the benefits.

The Rwanda Government did not wait for this quantified evidence to pay more attention to such initiatives and has considered the development of model green villages as a tool for reaching the national and long-term priorities (EDPRS 2 and vision 2020) since 2016 already. The government has now mandated that at least one green village per district should be developed under the National Human Settlement Policy and Strategy and the Integrated Development Programme. Accordingly, the replication and up-scaling analysis of the green villages has gained considerable importance among the stakeholders, as evidenced by the plans spearheaded by MINALOC and Rwanda Housing Authority.

The third part of this report is devoted to this extension process and is organized as follows. First, we will examine the costs and benefits related to the planned extension (up to 100 households) of the Rubaya village. Second, we will propose a business plan for the up-scaling of green villages in Rwanda. Such analysis will be based on the cost evidences collected in Rubaya and in Rweru. Finally, we will also examine the macro-economic and poverty reduction effect that such important investment might generate.

2. Extension of the Rubaya green village

The extension (to 100 households) of the Rubaya green village, as proposed by a new Green Climate Fund (GCF) supported project to be implemented by FONERWA, can simply be modelled by considering the costs and benefits per household in the actual situation and multiplying it by 57. Adding 57 households will generate an additional cost of 1.16 million USD over 30 years (using a 6% discount rate) and benefits of around 1.56 million USD over 30 years (using a 6% discount rate) leading the an additional NPV of 0.40 million USD (table 40).

Table 40 : NPV of the extension of the Rubaya village (USD)

		15 years	20 years	30 years
3%	NPV	192'697	491'630	972'179
6%	NPV	-12'830	165'912	399'412
10%	NPV	-205'030	-112'747	-19'817
13%	NPV	-308'116	-250'929	-203'016

In terms of investment costs, 800'000 to 900'000 USD are necessary to support the extension of the Rubaya green village to 100 households. This estimate is strictly based on the actual village, no hypothesis on the potential economy of scale nor efficiency gain from experience is considered. Note also that adding the solar lamps and irrigation components for 100 households will cost around 20'000 USD.

3. Scaling up of the green village models

3.1 Business plan

Setting up the business plan for the extension of the green village model all over Rwanda requires evidence on the costs. Section 3 of part II has presented the costs for the village of Rubaya. Total Investment costs amounted to 633'000 USD or around 14'700 USD per beneficiary household. The related operation costs amount to 17'700 USD/y, i.e. around 412 USD per beneficiary household per year.

The Rubaya village corresponds to one specific situation and investment decisions. The project includes building individual houses with biogas systems, water harvesting systems, distributing cows and terracing lands. However, solar lamps were not installed. A school has also been built (through the Ministry of Education), leading to additional investment and operation costs. When we visited the recently developed village of Rweru (Bugesera), we noticed that the investment decisions were different. In Rweru, "4 in 1" houses (4 independent flats in one house) have been built. They are bigger and of better condition than in Rubaya (bricks, painting). They also dispose of a better water delivery system and of solar lamps. However, in the Rweru village, no biogas system[9], nor terrace (it is not necessary in Rweru since the area is flat) and schools have been realized. Cows have been distributed in both villages.

Table 41 compares the investment costs between the villages of Rubaya and Rweru. We notice that the houses cost around 50% more in Rweru (10'728 USD/household vs 6'871 USD/household if we do not include the biogas system). As mentioned, this difference might be explained by the higher housing quality in Rweru.

Table 41 : Comparison of investment costs per household in Rubaya and Rweru (in USD)

	Rubaya	Rweru
House, water and energy components	**Individual house**	**4 in 1 house**
House construction	2'382	9'769
Water tank and sanitation	4'441	696
Digester and biogaz	3'855	
Electricity		263
Total : House without biogas system	**6'823**	**10'728**
Total : House with biogas system	**10'677**	
Others components		
Cowshed	50	326
Cows (2 per household)	1'538	
Terraces	289	
School	1'073	
Greening and nursey beds	179	230
Irrigation	200	
Total Inv. Cost	**13'807**	**11'284**
Total Inv. costs (house, biogaz, cows, school, terraces, electricity)	**14'271**	**17'950**

Combining the situations in Rweru and Rubaya allows to compute investment costs per household. We also consider the budgeted cost for irrigation (even if the investment has not been made so far). If we add the biogas component, the school, the cows (considering 2 cows per household since half of them

[9] Some biogas equipment was being tested at the time of our visit.

are distributed to poor households in the surroundings) and irrigation in Rweru, the total investment cost would amount to 17'950 USD per household (no terraces are however considered). Adding irrigation and solar lamps in Rubaya, the total investment cost would amount to 14'261 USD per household (terraces are included). In Rweru, the construction of one school is planned and a community house has already been built. Cows were also distributed. The investment costs for cows and education were however not available in Rweru.

These values might represent upper and lower benchmarks for the investment cost. The lower benchmark might correspond to the costs for villages in mountainous areas (individual house), while the upper benchmark might be relevant for flat areas (4 in 1 better quality houses) including water harvesting systems, irrigation, biogas, cows, school and terracing (in mountainous areas).

In order to set a business plan, we adopt the following hypothesis:

- 30 additional green villages will be built in Rwanda until 2020-2025, i.e. one per district as planned by the national strategy. Each village will count 100 households. The average household's size is 4.5 persons.
- Considering the topography of Rwanda, we consider that around 50% of the village would be built in sloping areas, therefore corresponding to the village of Rubaya (individual house and terraces) and 50% in flat areas, this time corresponding rather to the situation of Rweru (4 in 1 better quality houses, without terrace).
- All projects will include the following components: Irrigation, distribution of cows, houses, water, sanitation and biogas systems, school, nursery beds and greening. Furthermore, terraces are built in the sloping areas. The average cost of a house is lower for Rubaya type village (according to the evidence collected).

The total investment costs are presented in table 42, they are estimated at 48.3 millions of USD. **This sum represents 1.8% of the budgeted spending of Rwanda , 4.2% of the development spending or 13.6% of the budget allocated to the rural development objective**[10] **for 2016** (according to MINECOFIN, 2016)**.**

Table 42 : Total investment costs (USD)

	Cost per household	Total costs	Units
15 villages (Rubaya types), 1500 households	**14'271**	21'405'838	USD
15 villages (Rweru types), 1500 households	**17'950**	26'925'194	USD
Total Inv. costs		**48'331'032**	

Table 43 allocates the total investment costs according to the main expenses and presents potential funding sources (based on what was planned in Rubaya). Note also that investment cost might be reduced because of the presence of scale economies. Indeed, lower construction costs might be negotiated if a larger quantity of houses and related infrastructures are ordered. However, as far as the project aims at involving the beneficiaries in the construction process (working thus at the local scale), such scale returns might also remain limited.

[10] The objective of rural development is to improve the quality of life and economic well-being of people living in rural areas. It represents 13% of the 2016/2017 budget allocation.

Table 43 : investment costs by expenses (USD)

	Inv. Costs	Units	Source of funds
Houses	26'721'482	USD	MINALOCA
Biogaz	11'563'953	USD	REMA
Greening and nursery bed	612'716	USD	REMA
Cows	5'179'230	USD	MINAGRI
Irrigation	600'000	USD	MINAGRI
Terraces	433'616	USD	MINAGRI
School	3'220'036	USD	Ministry of Education

The project will also generate operation costs for the Rwanda public sector mainly related to the activities of the schools (arounds 100'000 USD/y for the 30 villages). The other operation costs (maintenance) will be supported by the beneficiaries.

3.2 Benefits of the replication

Considering the previous information, it is straightforward to estimate the benefits that will be generated by the 30 green villages by using the rate of return and benefit by beneficiary estimated in the CBA (central estimate). Table 43 considers the additional net present value considering 3000 households. Table 44 provides an alternative estimate based on the amount of investment. The estimated net present values lie around 21 to 23 million USD after 30 years (considering a 6% discount rate). On average, this represents between 700'000 and 760'000 USD per year.

Table 42 : Total net present value of projected replication, extrapolated considering the number of beneficiaries (USD)

		15 years	20 years	30 years
3%	NPV/year	10'141'946	25'875'261	51'167'330
6%	NPV/year	-675'261	8'732'197	21'021'706
10%	NPV/year	-10'791'030	-5'934'065	-1'042'975
13%	NPV/year	-16'216'614	-13'206'769	-10'685'043

Table 43 : Total net present value of projected replication, extrapolated considering the rate of return (USD)

		15 years	20 years	30 years
3%	NPV	11'004'399	28'075'648	55'518'510
6%	NPV	-732'684	9'474'768	22'809'355
10%	NPV	-11'708'681	-6'438'687	-1'131'667
13%	NPV	-17'595'646	-14'329'850	-11'593'681

3.3 Macro-economic effects: Multiplier analysis

The up-scaling of the project will also have macro-economic consequences via the multiplier effect.

The multiplier effect, as postulated by the Keynesian theory, constitutes a snowball effect applied to the investment. The multiplier effect considers that investing in one sector (direct effect) will stimulate the economic activities elsewhere in the economy (indirect effect) leading to a final increase in the national or regional income larger than the initial investment or spending. For example, considering green villages, the government will indeed pay the workers to build the related infrastructures. These workers will use part of this income for consumption. This consumption provides a new income for the seller and leads to an additional consumption from the seller. The process goes on and on leading to successive production increases. The importance of the multiplier effect thus depends on the amount of money that is devoted to the consumption of goods and services that are produced in the Rwanda economy (i.e. the marginal propensities to consume and to import are key parameters).

The value of the multiplier for the Rwanda economy remains unknown and actual data did not allow us to compute an original estimate. Diao et al (2014) examine the future growth prospects of Rwanda using a dynamic general equilibrium model to display the trade-off between rapid growth and structural change. They determine a growth multiplier of 1.32 for the crop sector, stating that an initial investment of 100 RWF in the food crop sector leads to a final increase in income of 132. This effect is large and might be explained by the strong linkage between the agricultural sector and the rest of the economy. MINAGRI (2013) uses a value of 2 for estimating the final effect of an initial increase in income for the workers in the National Dairy Strategy.

Based on the previous findings, we will consider a multiplier of 1.3 on the initial investment of 48.3 millions USD (central estimate), leading to a potential increase in GDP in the long run between 62.3 millions USD (0.8% of GDP). This means that the project's investment will generate an increase in GDP of around 0.8%. This does however not include all the intangible benefits that we accounted for in the CBA analysis.

We might also apply a multiplier effect of 2 on the additional income that is created by the project (the income from crop and livestock production), which is equal to around 690 USD per household. Scaling up the project to reach 3000 household, this would generate an indirect effect on jobs creation representing 4.13 million USD per year.

3.4 Effect of poverty

Scaling-up the project will also have an effect on poverty: considering that the project brings out of extreme poverty the 3000 beneficiary households (around 13'500 people). This would lead to a decrease of 0.71% of the country's extreme poverty rate (16.3% in Rwanda in 2015).

3.5 Synthesis of the scaling-up

Overall, the scaling-up of the project (up to 30 villages and 3000 beneficiary households) in Rwanda will:

- Necessitate an investment for a total amount estimated at 48.3 millions of USD (1.8% of the budgeted spending of Rwanda for year 2016, 4.2% of the development spending or 13.6% of the budget allocated to the rural development objective).
- Necessitate operation costs for the Rwanda public sector estimated at 100'000 USD/y.
- Generate net welfare gain for the beneficiaries estimated at around 21 to 23 millions of USD after 30 years in the form of increased income, better health, better education and better quality of life.
- Generate a final increase of the GDP of 62.3 millions (multiplier effect).
- Generate a decrease of 0.71% of the extreme poverty rate of the country.

Part IV: Conclusion

This report has been devoted to the assessment of the economic, social and environmental benefits of the Rubaya green village on the one hand and of the potential benefits of project replication on the other.

In order to fulfil the previous objectives, a 3-step analysis has been realized. First, we studied the context, the characteristics, the logic of actions and the main outcomes of the Rubaya green village experience. In this process, we identified the costs and the benefits of the project and their determinants. Secondly, we realized a CBA in order to judge the project's efficiency. The CBA consists in estimating in monetary units the additional benefits and costs related to the project over its life span. Finally, we adopted a prospective view trying to extrapolate the future costs and benefits that the up-scaling of the project might generate.

Overall, the report leads to the following major results:

- The Rubaya Green village necessitated an initial investment ranging between 570'000 and 710'000 USD. The largest share of the investment costs are related to the construction of the infrastructure related to water and sanitation (30%) and biogas production and delivery system (26%). The project also generates operating costs between 17'000 to 22'000 USD per year.
- The project generated benefits related to an increase in agricultural and livestock production, but also to lower health impacts (water, sanitation, indoor air pollution), time savings (lower distance to fetch water, lower need to collect wood and shorter distance to school), better living conditions (improved houses, lower exposure to natural disasters) and education (higher long-term income). The total benefit of the project has been estimated at around 1,2 million USD over 30 years (using 6% discount rate). The main benefits come from livestock (21.5%) and better housing (21.4%).
- Considering our preferred discount rate (6%) and time spans (20 and 30 years), the project efficiency is high, leading to benefits surpassing the costs by 15% to 35%. The rates of return also appear to be high (20% and 47%), way higher than common private sector rates of return. The internal rate of return over 30 years is 8.9% and 7.7% over 20 years. Finally, the payback period is about 15 years considering a 6% discount rate. Therefore, the project's efficiency is high if a sustainable, social and long-term perspective is adopted. The Rubaya green village therefore represents an efficient allocation for public resources.
- The sensitivity tests confirm the stability of the previous conclusions. These results therefore provide decisive and reliable arguments in favor of the project's extension and replication (up-scaling).
- The extension (to 100 households) of the Rubaya green village will generate additional costs for 1.16 million USD over 30 years (using a 6% discount rate) and benefits of around 1.56 millions USD over 30 years (using a 6% discount rate) leading to an additional NPV of 0.4 millions (table 40). Focusing on the investment cost, 800'000 to 900'000 USD are necessary to support the extension of the Rubaya green village to 100 households.
- Scaling the project up to 30 additional green villages in Rwanda (3000 beneficiary households) would require an investment of 48.3 millions of USD. This sum represents 1.8% of the budgeted spending of Rwanda for 2016, 4.2% of the development spending or 13.6% of the budget allocated to the rural development objective. The estimate take also into account the cost information available for the newly constructed village of Rweru, as well as available information on the IDP Model Villages in Rwanda.
- The up-scaling of the project will generate additional benefits leading to a net present value of 21 to 23 millions USD (after 30 years, considering a 6% discount rate).
- The up-scaling will also generate indirect economic effects, which are estimated at 0.8% of national GDP (63.3 millions of USD).
- Scaling-up the project will also have an effect on poverty leading to a decrease of 0.71% of the extreme poverty rate of the country (16.3% in Rwanda in 2015).

References

Atampugre Gerald (2014), Cost and Benefit Analysis of the adoption of Soil and Water Conservation methods, Kenya, International Journal of Scientific and Research Publications, Volume 4, Issue 8, August 2014

Bishop, J.T. (ed.) 1999. Valuing Forests: A Review of Methods and Applications in Developing Countries. International Institute for Environment and Development: London.

Bizimana J. (2011), Economic impact analysis of radical terracing project, Case Study Cyabingo sector in Gakenke District, Bachelor Thesis, Faculty of agricultural engineering and environmental sciences, Higher institute of agricultural and animal Husbandry

Bizoza and De Graaff (2010), Financial cost–benefit analysis of bench terraces in Rwanda, Land Degrad., Develop. 23: 103–115 (2012)

Boissiere M. (2004), Rationale for Public Investments in Primary Education in Developing Countries, Background Paper for the Evaluation of the World Bank's Support to Primary Education, OED Working Papers, World Bank

Borde A. and Rangira L. (2016), Assessment of the economic, social and environment costs and benefits of the REMA/PEI Rubaya demonstration project, CBA and Business Plan, Report prepared as part of the: UNDP-UNEP Poverty-Environment Initiative (PEI) in Rwanda, Draft

Branca Giacomo, Nancy McCarthy, Leslie Lipper and Maria Christina Jolejole (2011), Climate Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management, the Mitigation of Climate Change in Agriculture (MICCA) Programme, FAO, Rome funded by the Government of Finland

Cavallo E. and Noy I. (2009), The economics of natural disasters: a survey, IDB working paper series, 124

Clay D. C, F. Byiringiro, J. Kangasniemi, T. Reardon, B. Sibomana, L. Uwamariya (1996), Promoting Food Security in Rwanda Through Sustainable, Agricultural Productivity: Meeting the Challenges of Population Pressure, Land Degradation, and Poverty, Productive Sector Growth and Environment Division Office of Sustainable Development Bureau for Africa U.S. Agency for International Development -USAID

Cook J., Kimuyu P., A. G. Blum, and J. Gatua (2015), A Simple Stated Preference Tool for Estimating the Value of Travel Time in Rural Africa, Environment for Development Discussion Paper Series May 2015, EfD DP 15-08

David J., Crow B. et Miles J., ICTD'12, March 12–15, 2012, Atlanta, GA, USA

Diao X., Bahiigwa G. and Pradesha A. (2014), The Role of Agriculture in the Fast-Growing Rwandan Economy, Assessing Growth Alternatives, FPRI Discussion Paper 01363

Duncan Thomas and Elizabeth Frankenberg (2002), Health, nutrition and prosperity: a microeconomic perspective, World Health Organization 2002 Bulletin of the World Health Organization 2002, 80 (2)

Eaton D. (1996), The economics of soil erosion: a model of farm decision-making, Environmental Economics Programme, Discussion Paper, DP 96-01, International Institute for Environment and Development

FAO (2011), Radical Terraces - Rwanda - Amaterasi y'indinganire, http://www.fao.org/3/a-au298e.pdf

GTZ and Advisory Service on Appropriate Technology (ISAT), Biogas Digest, Volume III Biogas - Costs and Benefits and Biogas – Programme Implementation

Haller L, Hutton G and Bartram J (2007), Estimating the costs and health benefits of water and sanitation improvements at global level. Journal of Water and Health. 5(4): p. 467-480.

Hutton G., Haller L. and Bartram J. (2007), Economic and health effects of increasing coverage of low cost household drinking-water supply and sanitation interventions to countries off-track to meet MDG target 10, World Health Organization, WHO/SDE/WSH/07.05

Hutton G., E. Rehfuess, F. Tediosi and S. Weiss (2007), Evaluation of the costs and benefits of household energy and health interventions at global and regional levels, World Health Organization

Hutton G and Haller L (2004), Evaluation of the non-health costs and benefits of water and sanitation improvements at global level. World Health Organization. WHO/SDE/WSH/04.04.

IFRC - International Federation of Red Cross and Red Crescent Societies (2016) Cost-Benefit Analysis of the Rwanda Red Cross Livestock rotation programme

Independent Economic Advisers (2009), Discount Rates for Environmental Benefits Occurring in the Far-Distant Future, research note, http://www.iearesearch.com/papers/discounting.pdf

IWG SCC (2013). Technical Support Document: - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866 - Interagency Working Group on Social Cost of Carbon, United States Government.

Kakuru W.; Kanyamibwa S.; Gatarabirwa W.; Nsabagasani C.; Nsengiyumva P. and Ndengera M. (2014). Total Economic Valuation of Mukura Forest Landscape, Rwanda. ARCOS, December 2014.

Kellenberg Derek and A. Mushfiq Mobarak, 2011, The Economics of Natural Disasters, Annual Review of Resource Economics, Vol. 3: 297 -312

Kossmann W., Pönitz U., Habermehl S., Hoerz T., Krämer P., Klingler B., Kellner C., Wit- tur T., von Klopotek F., Krieg A. and Euler H. (undated). Biogas Digest Volume I – IV. German Agency for Technical Cooperation (GTZ). Eschborn. Germany.

MINAGRI - Ministry of agriculture and animal resources (2009), Updating the master plan of the milk chain in Rwanda

MINAGRI - Ministry of agriculture and animal resources (2013), National Dairy Strategy

MINECOFIN - Ministère des finances et de la planification économique (2016), Le budget national, Un guide pour citoyen pour l'année fiscale 2015/2016

Mullan Katrina (2014), The Value of Forest Ecosystem Services to Developing Economies, Working Paper 379, CGD Climate and Forest Paper Series #6

NISR - National Institute of Statistics of Rwanda (2015), Statistical Yearbook, 2015 Edition

NISR - National Institute of Statistics of Rwanda (2015), Ministry of Health (MOH) and ICF International. 2015. Rwanda Demographic and Health Survey 2014-15. Rockville, Maryland, USA: NISR, MOH, and ICF International.

NISR - National Institute of Statistics of Rwanda (2015), EICV3 Thematic report, Agriculture

OCDE (2006), Cost-Benefit Analysis and the Environment: Recent Developments, Paris

Okuyama Y., Critical review of methodologies on disaster impact estimation, background paper was prepared as an input into the joint World Bank – UN Assessment on the Economics of Disaster Risk Reduction.

Paul Watkiss Associates (2016), Lot 3 Economic and Financial Analysis of Component 3: Watersheds and Ecosystems, Draft document, Submission 16th December

Psacharopoulos G. (2014), Benefits and Costs of the Education Targets for the Post-2015 Development Agenda, Post-2015 Consensus, Working Paper as of July 17th, 2014, Copenhagen consensus center

Ready R. and Navrud S., International benefit transfer: Methods and validity tests, Ecological Economics 60 (2006) 429–434

Renwick M., Subedi P.S., and Hutton G. (2007), A cost-benefit analysisof national and regional integrated biogas and sanitation programs in Sub-saharan Africa, Biogas for better life: an African initiative, Winrock International

Saiz G., F. M. Wandera, D. E. Pelster, W. Ngetich, J. R. Okalebo, M. C. Rufino, K. Butterbach-Bahl (2016), Long-term assessment of soil and water conservation measures (Fanya-juu terraces) on soil organic matter in South Eastern Kenya, Geoderma 274 (2016) 1–9

Santos Telles Tiago, Maria de Fátima Guimarães and Sonia Carmela Falci Dechen (2011), the costs of soil erosion, R. Bras. Ci. Solo, 35:287-298, 2011

Schultz T. Paul, 2005, Productive Benefits of Health: Evidence from Low-Income Countries, center discussion paper no. 903, economic growth center, Yale University

Smith J.U., The Potential of Small-Scale Biogas Digesters to Alleviate Poverty and Improve Long Term Sustainability of Ecosystem Services in Sub-Saharan Africa DFID NET-RC A06502

Shrestha, R., Loomis, J., 2001. Testing a meta-analysis for benefit transfer in international outdoor recreation. Ecological Eco- nomics 39, 67–83.

Turpie Jane, Benjamin Warr and Jane Carter Ingram (2015), Benefits of forest ecosystems in ZamBia and the role of redd+ in a Green economy transformation, Ecosystem Services Economics Unit, Division of Environmental Policy Implementation (DEPI), United Nations Environment Programme (UNEP).

Twesigye-Bakwatsa C. and Bizoza A.R., 2014, Assessment of the economic, social and environmental benefits of the Rubaya Demonstration Project and Benefits of widespread Project Replication, Rwanda Environment Management Authority (REMA)Poverty and Environment Initiative (PEI), Draft Report (Revised)

Umuratwa Higiro Sharoni, Mbera Zenon, Mbabazi Mbabazize (2016), Assessment of the effect of community empowerment projects on enhancing poverty alleviation in rwanda. A case study of Rubaya demonstration project, European Journal of Business and Social Sciences, Vol. 5, No. 01, April 2016. P.P. 321 - 346 URL: http://www.ejbss.com/recent.aspx-/

UNEP-UNDP (2012), Rubaya Demonstration Project Integrated environmental management and poverty reduction: Making the case for real change among Rwanda's poor through sustainable socio-economic growth path, July 2008 – June 2011, UNEP-UNDP

UNDP/UNEP (2006), Economic analysis of natural resource management in Rwanda, PEI-II

Vögeli Y., Lohri C. R., Gallardo A., Diener S., Zurbrügg C. (2014). Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland

Whittington D., Mu X., Roche R. ,1990, Calculating the value of time spent collecting water: some estimates for Ukunda, Kenya. World Dev 18, pp 269–280

World Bank (2017), Le coût de la dégradation de l'environnement au Maroc, Environment and Natural Resources Global Practice Discussions Paper 5, World Bank Group Report Number 105633.MA

World Bank (2004), Education in Rwanda: rebalancing resources to accelerate post-conflict development and poverty reduction

WHO Online database, Environmental burden of disease: Country profiles, http://www.who.int/quantifying_ehimpacts/national/countryprofile/intro/en/

European Union

Norwegian Ministry of Foreign Affairs

Swedish International Development Cooperation Agency

Spanish Ministry of Foreign Affairs and Cooperation Development

UK Department for International